Soil Erosion by Water as Related To Tillage and Surface Residues, Terracing, and Contouring in Eastern Oregon

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ABSTRACT

Soil erosion by water was estimated for combinations of three management types in the B7, B8, and B9 Major Land Resource Areas (large areas of similar topography, soils, climate, and cultural operation) of eastern Oregon. The three management types were tillage and residue handling, terracing, and contouring. The Universal Soil Loss Equation was applied along with detailed factor information used in conservation planning.

Wheat-fallow and wheat-pea sequences predominate on the tilled cropland, which constitutes about 43 percent of the land area. Differences of potential soil erosion in the three Major Land Resource Areas not only differed because of differences in the rainfall and runoff energy factor, but also because of major differences in soil tolerance for soil erosion and percentage of steeper slopes.

Slope steepness was the primary factor determining which combination of the three management types was needed. Soil erosion could not be held below tolerance values in the wheat-fallow sequence for slopes exceeding 20 percent even with the best of all three management types; a combination of all three management types were needed for slopes between 12 and 20 percent; tillage and residue handling along with contour operation sufficed on slopes of less than 12 percent. On slopes of less than 5 percent, none of the three control measures was needed. The wheat-pea sequence allowed no relaxation of control measures found necessary for controlling erosion in the wheat-fallow sequence.

In the study area, consisting of 1.94 million hectares, 1.3 million tonnes of small grain residue are produced annually. Erosion control measures affected the amount of residue available for bioenergy harvest; for the test area, as a whole, 50 to 70 percent of the residue produced is available for harvest; the proportion of harvested area from which residues can be taken ranges from 98 to 62 percent of harvested area. Concentrations of harvestable (for bioenergy use) residue in wheat-fallow range from 0.8 to 2.6 tonnes/ha depending on erosion control measure(s) applied; if considered on a tilled cropland basis, these concentrations would be 0.45 to 1.3 tonnes/ha.

KEYWORDS: Bioenergy harvest, tilled cropland, adjacent non-tilled cropland, nutrients in residue, soil erosion, soil steepness, soil management, wheat.

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This manuscript contains background information used in preparing the abridged publication: R. R. Allmaras, S. C. Gupta, J. L. Pikul, Jr., and C. E. Johnson. 1979. Tillage and plant residue management for water erosion control on agricultural land in eastern Oregon. Journal of Soil and Water Conservation 34(2):85-90.

SOIL EROSION BY WATER AS RELATED TO MANAGEMENT OF TILLAGE AND SURFACE RESIDUES, TERRACING, AND CONTOURING IN EASTERN OREGON

By R. R. Allmaras, S. C. Gupta, J. L. Pikul, Jr., and C. E. Johnson[1]

INTRODUCTION

Tillage and plant residue management is now receiving more attention and evaluation as a method for control of soil erosion by water. Three events of the past 10 years have contributed to this renewed interest: (1) the control of nonpoint sediment pollution as mandated in the 1972 Public Law 92-500 (revised in 1977 and now P.L. 95-217), (2) recent interest in the use of plant residues for bioenergy production, and (3) the development of many new conservation tillage and planting systems. Larson et al. (*1978*) and Larson (*1979*) discussed current appraisals for use of plant residues to produce bioenergy. Some of the recent trends in both machinery and crop residue management were reviewed for the Pacific Northwest by Papendick and Miller (*1977*) and for a national viewpoint by the Soil Conservation Society of America (*1973*).

On the characteristically steep croplands of the Pacific Northwest, erosion control must often be attained by a combination of three management types--tillage and residue placement, terracing to reduce slope length, and contour operation. These managements are described, respectively, by the cover and management, slope length, and supporting practice factors in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, *1965*; *1978*); these are the factors that can be used along with other factors and considerations to provide site specific control of water erosion. Flexibility in the choice of these management types is what makes control site specific.

The USLE has been used as a conservation planning tool since 1974 in the Pacific Northwest. Since about 1960 it has been used extensively in the Midwest, but significant modification was necessary for the recent application in the Pacific Northwest. Predictions of annual erosion using the USLE are time-averaged for a specified climate and crop sequence and are made as if the whole field is treated similarly as regards tillage, residue cover, terracing,

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and contouring. This study tested predictions over larger areas such as the Major Land Resource Areas (MLRA).[2]

The northeastern Oregon study area (fig. 1) comprises about 8 percent of the Northwestern Wheat and Range Region (Austin, *1965*). MLRA significant to agriculture in northeastern Oregon are the Columbia Basin (B7), Columbia Plateau (B8), and Palouse-Nez Perce Prairies (B9). The MLRA are distributed among Oregon, Washington, and Idaho as shown in figure 2. Agriculture in each of these MLRA is determined by a unique combination of natural and cultural features; however, these MLRA, as a group, have many similar features that contribute to a serious water erosion hazard.

Cool and wet winters follow warm and dry summers, a combination that produces sparse vegetative cover in winter even where intensive agriculture is not practiced and native vegetation persists. Late summer arid conditions limit crop species to those that mature for harvest early in the summer. Only under irrigation can long-season crops be grown. Thus, the choice and rotation of crops in this dryland agriculture are limited. Climatic classification of the study area ranges from semiarid to semihumid.

The smooth to deeply dissected plains and plateaus of the study area generally have steep and long slopes susceptible to severe sheet and rill erosion wherever there are no practices to limit or break up the slope length. Soils

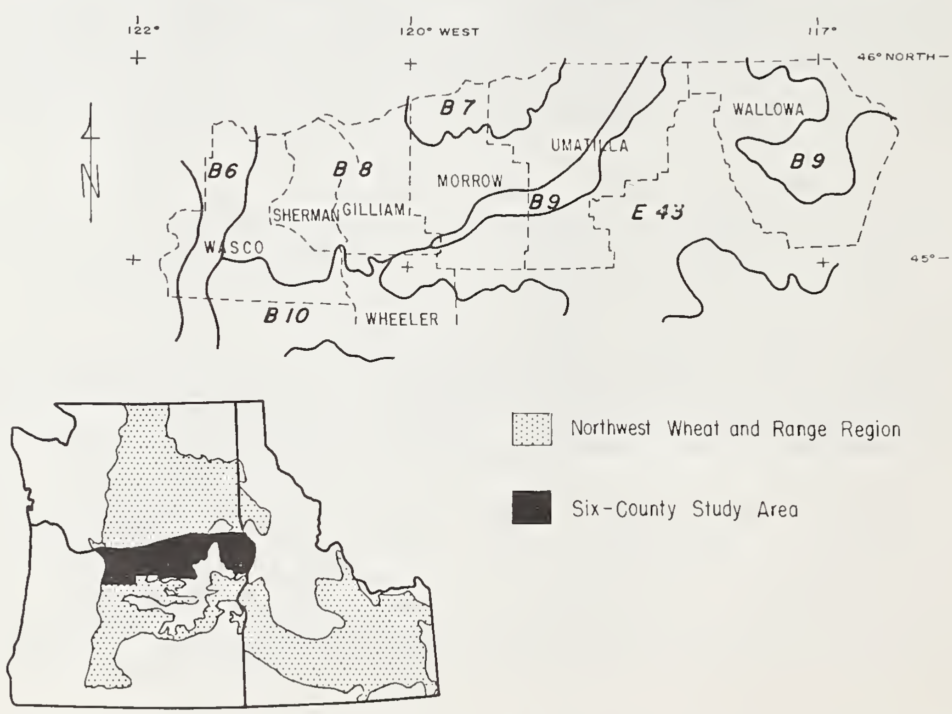

Figure 1.--Six-county study area located in the Northwest Wheat and Range Region.

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[2]These are areas of similar topography, soils, climate, and cultural operation.

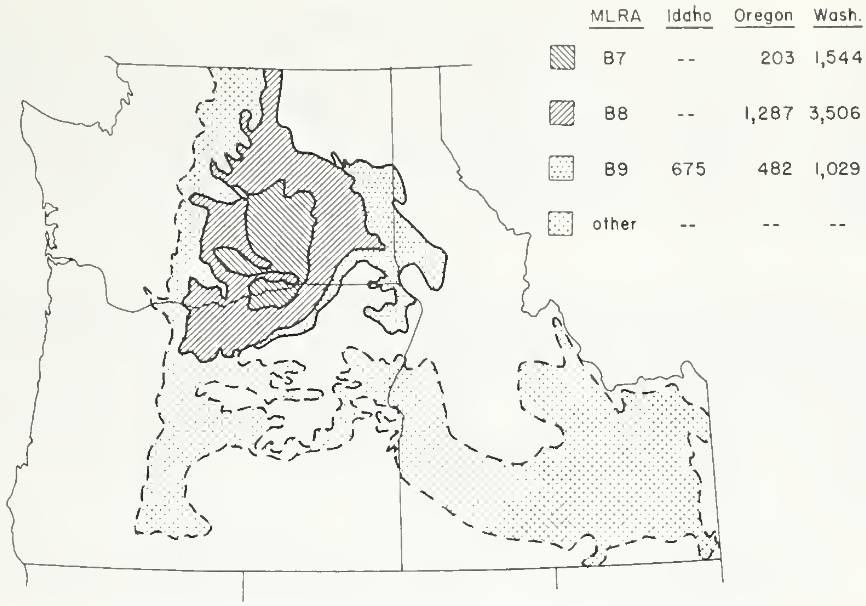

Figure 2.--Distribution of Major Land Resource Areas B7, B8, and B9 among States within the Northwest Wheat and Range Region (legend figures are in thousands of hectares).

in the study area are derived mainly from loess mantles overlying basalt bedrock. Depths of loess are much greater on north- and east-facing than on west- and south-facing slopes. Loessial deposits are, in general, much deeper in the northern (Washington) portion of the combined B6, B7, B8, and B9 MLRA than in the southern (Oregon) portion (National Research Council, *1952*). Basalt bedrock often outcrops on the steeper slopes. The rooting zone is often restricted to less than 100 cm by shallow soil mantles or layers impervious to rooting. Poor soil structure, low organic matter content, and high silt composition portend high soil susceptibility to soil erosion by water.

Our first objective was to analyze which management combinations (tillage and residue management, terracing, contour operation, or any combination of the three) will maintain upland soil erosion losses within loss tolerances set by the Soil Conservation Service (SCS). An "adapted" USLE has been used since 1974 as a conservation planning tool to control water erosion in agriculture and rangelands of the Pacific Northwest. Modifications, especially of the rainfall energy, slope steepness, and slope length factors, were made by McCool et al. (*1976*) to adapt the original USLE (Wischmeier and Smith, *1965*) used elsewhere in the United States.

The cover and management factor in the USLE can be readily obtained from tillage and residue management alternatives chosen for analysis in this manuscript; slope length is changed whenever terracing is used to reduce the length of uninterrupted slope. Our analysis also takes into account the expected terrace layout consistent with the SCS terrace construction variance[3] for use when the combined rainfall and runoff erosion factor is less than 61.

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[3]Private communication with Don Stettler, SCS, Portland, Oreg.

A second objective was to identify where plant residues may be harvested for energy or other uses and still maintain control of soil erosion by water. This objective was prompted by similar analyses performed by Larson et al. (*1978*) on MLRA in Minnesota for an agriculture much different from that in eastern Oregon. Comparable analyses have now been made for the southeastern States (Campbell et al., *1979*) and the Corn Belt (Gupta et al., *1979*; Lindstrom et al., *1979*).

While these two objectives address tillage and residue management for control of soil erosion by water, there are other benefits from tillage and residue management. Some of these are wind erosion control, water conservation as soil stored water, return of nutrients, and runoff control. A more complete discussion of these benefits from residue management is given by Oschwald (*1978*). Any decision about crop residue removal must respond to all of these conservation and environmental effects.

RESOURCE CHARACTERISTICS AND SOIL EROSION MODEL

Our soil erosion model uses the USLE:[4]

$$A = K\ R_T\ SL\ C\ P$$

where A is the soil loss in tonnes/ha per yr,
K is the soil erodibility factor expressed in tonnes/ha per yr,
R_T is the annual combined rainfall and runoff energy factor,
SL are the slope steepness and length factors,
C is the cover and management factor, and
P is the practice factor.

Three categories of inputs were used for the estimation of erosion within a MLRA. These are: (1) a detailed listing of soil types in each MLRA; (2) the R_T, S, and K parameters of the USLE associated with each soil type; and (3) systematic combinations of the L, C, and P factors. The R_T, S, and K parameters cannot be changed, but the L, C, and P factors are manageable tools for soil erosion control. The C factor is related to tillage and residue management; the L factor is related to slope-length reduction from terracing; and the P factor is related to field operations on the contour. An additional fourth input of crop yields was used to assess availability of residues for energy or animal feed consistent with control of water erosion.

Our procedures generally followed those of Gupta et al., (*1979*); however, natural features of MLRA B7, B8, B9, and B9 (Wallowa) often required significant deviations from the general procedure of Gupta et al. originally applied to MLRA in the Corn Belt.

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[4]Metric units are used throughout. See Wischmeier and Smith (*1978*) for conversion multipliers: A in tonnes/ha per yr = (2.242) x soil loss in tons/ha per yr; K in tonnes/ha per yr = (1.292) x soil erodibility factor in tons/acre per yr; R_T in metric system = (1.735) x combined rainfall and runoff factor in English System.

Fixed Factors of the USLE

In this study, the most detailed level of soil description is the "soil type - slope phase" combination; for convenience, other phases, such as rockiness, stoniness, soil depth, or solum characteristic, will be distinguished and included with soil type description. Any reference to soil type includes type and phase other than slope.

Listings of soil types with their slope phases and areas were developed separately for each of the six counties and MLRA B7, B8, and B9 as shown in figure 1. Soil type listings were compiled from soil mapping units within county soil surveys (Mayers, *1964*; Soil Conservation Service, *1972*; Harper et al., *1948*), the 1967 Conservation Needs Inventory (CNI) (USDA Conservation Needs Inventory Committee, *1971*), and River-Basin Planning Inventories (Dyksterhuis et al., *1969*; Norgren and Simonson, *1969*; Norgren et al., *1969*). Whenever a conflict of information on soil type names or areas arose, we relied on greater accuracy of the county soil survey maps and associated soil descriptions. Whenever possible, we also utilized SCS slope phases.[5]

Two methods of estimating areas of the MLRA are shown in table 1: the CNI estimates were obtained from maps delineating MLRA boundaries; the soil type summary (STS) estimates were obtained by summing areas of soil type - slope phases, first within counties, then over MLRA. Overall estimates of MLRA B7 + B8 + B9 area by the two methods agreed to within 2.4 percent; the maximum difference between method estimates for a county was 10.1 percent; within counties and MLRA, the estimates generally agreed within ±10 percent. Total land estimates (table 1, column 2) for each county were equal to or greater than their respective CNI or STS totals because some counties contained MLRA other than B7, B8, or B9. These MLRA are B6 (Eastern Slope Cascade Mountains), B10 (Upper Snake River Lava Plains and Hills), and E43 (Northern Rocky Mountains).

For each soil type - slope phase, a fraction tilled was estimated from soil surveys and from consultation with SCS personnel.[6] Thus, three classes of land were determined, based on the fraction tilled:

a) Tilled cropland was the tilled fraction of land in a soil type - slope phase.

b) Nontilled adjacent cropland was the nontilled fraction of land only in those soil type - slope phases which contained some tilled land.

c) Forest and rangeland occurred in the soil type - slope phases having a tilled fraction equal to zero.

Detailed listings of the soil type - slope phases and associated information are shown (for both tilled cropland and nontilled adjacent cropland), respectively, in appendix tables 1, 2, and 3 for MLRA B7, B8, and B9. Appendix

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[5]Source: Soil Conservation Service, Intermittent. OR-Soils-1 (Soils Interpretations for Oregon). Soil Conservation Service, Portland, Oreg.
[6]Personal communication with Rudolph Mayko, SCS, Portland, Oreg.

Table 1.--*Distribution of land in Major Land Resource Areas B7, B8, and B9 in 6 northeastern Oregon counties*

County	Total land[2] [3]	B7 CNI	B7 STS	B8 CNI	B8 STS	B9 CNI	B9 STS	Total CNI	Total STS
		Land area estimated by two methods[1] in indicated MLRA							
		Thousands of hectares							
Gilliam	311.4	--	13.8	308.1	295.6	--	6.3	308.1	315.7
Morrow	527.7	108.2	114.3	257.3	244.6	52.4	49.6	417.9	408.5
Sherman	209.8	--	--	209.8	211.9	--	--	209.8	211.9
Umatilla	835.9	95.1	94.3	268.8	248.2	147.5	138.7	511.4	481.2
Wallowa	832.6	--	--	--	--	281.9	254.7	281.9	254.7
Wasco	626.1	--	--	242.6	253.0	--	--	242.6	253.0
Total	3343.5	203.3	222.4	1286.6	1253.3	481.8	449.3	1971.7	1925.0

[1]Conservation needs inventory (CNI) estimates obtained from a 1967 inventory (Conservation Needs Inventory Committee, *1971*). Soil type summary (STS) estimates obtained from detailed listings of soil types and their estimated area.

[2]Source: Yearbook Statistical Committee, USDA. 1969. Agricultural Statistics, 1969. U.S. Government Printing Office.

[3]The difference between column 2 and column 9 estimates the amount of land area in MLRA other than B7, B8, B9.

Note: Dashes indicate no Major Land Resource Area in the county indicated.

tables 4, 5, and 6 contain detailed listings of the forest and rangeland for MLRA B7, B8, and B9, respectively.

In table 2, tilled cropland estimates, from summation of the soil type - slope phase listings, are compared with the total cropland estimates resulting from the 1969 Census of Agriculture (U.S. Bureau of Census, *1969*). When summed over counties, the soil type - slope phase listings are a 2-percent overestimate of the total cropland estimate; within counties the average discrepancy is ±11 percent. Table 3 shows composition of total cropland within the various counties as compiled in the 1969 Census of Agriculture. Total cropland area includes the sum of harvested cropland, summerfallow, pasture or grazing, and other minor uses. Pasture or grazing totals are a larger percentage of the total cropland in counties with significant amounts of MLRA other than B7, B8, and B9. Yet, the larger tilled cropland area than total cropland in table 2 and the assumption (to be discussed later) that nearly all of the tilled cropland is either fallow-wheat (*Triticum aestivum* spp. *vulgare* (Vill., Host) or *Triticum aestivum* ssp. *compactum* (Host)) or wheat-peas (*Pisum sativum* L.) indicate a positive bias of tilled cropland greater than the 2 percent shown in table 2.

Table 2.--*Tilled cropland in Major Land Resource Areas B7, B8, and B9 in 6 northeastern counties as compared to Bureau of Census estimates for the counties*

County	Total[1] cropland	Tilled cropland estimates based on soil types[2] and their proportion tilled			
		B7	B8	B9	Sum
	Thousands of hectares				
Gilliam	108.8	3.7	117.4	4.7	125.8
Morrow	165.6	[3]26.9	132.5	12.9	172.3
Sherman	115.8	--	114.7	--	114.7
Umatilla[4]	255.1	46.5	175.7	51.6	273.8
Wallowa[5]	51.5	--	--	38.4	38.4
Wasco[6]	103.0	--	89.9	--	89.9
Sum over counties	799.8	77.1	630.2	107.6	814.9

[1]Source: U.S. Bureau of Census (1969). Total cropland is all land in crop on farms.

[2]Each soil type had an estimated area along with an estimated fraction tilled.

[3]This cropland estimate was reduced from 50,420 to account for 23,550 ha cropland in U.S. Government Reservation and was not included in 1969 Census report of county cropland.

[4]Assumed that E43 (Northern Rocky Moutains) contained negligible amounts of cropland.

[5]Assumed that only negligible amounts of cropland occurred in E43.

[6]Assumed that all cropland in this county was contained in B8; however, there are small land areas, especially of orchards in B6 (Eastern Slope Cascade Mountains) and irrigated small grain and forages in B10 (Upper Snake River Lava Plains and Hills).

Note: Dashes indicate no Major Land Resource Area in the county indicated.

Irrigated land totals, most of which are tilled cropland, are highest in those counties with significant areas of MLRA B7 (tables 2 and 3). Significant irrigation of forage crops is also practiced in Wallowa County, either in MLRA B9 or E43; in Wasco County most of the irrigation is practiced in MLRA B6. Since 1969, irrigated land has increased by about 43,000 ha in Umatilla and Morrow Counties, primarily in the arid sandy textured soils in MLRA B7. This new irrigated land represents about an 83 percent increase. The USLE does not apply to water erosion under irrigated conditions. Consequently, irrigated areas and production were purposely not included in this analysis.

Table 3.--*Cropland types in 6 northeastern Oregon counties comprising Major Land Resource Areas B7, B8, and B9 (1969)*[1 2]

County	Distribution of cropland area					
	Total[3]	Harvested	Pasture or grazing	Cultivated summerfallow	Other[4]	Irrigated
	Thousands of hectares					
Gilliam	108.8	46.8	10.0	48.1	3.8	2.1
Morrow	165.6	73.8	8.7	72.6	10.5	8.4
Sherman	115.8	52.1	3.7	54.2	5.7	.6
Umatilla	255.1	143.6	14.9	82.4	14.2	29.3
Wallowa	51.5	25.3	13.5	9.8	2.9	13.4
	103.0	43.0	11.5	36.3	12.3	9.1
6-county total	799.8	384.6	62.3	303.4	40.4	62.9
Percent	100	48.1	7.3	37.9	6.2	([5])

[1]MLRA B8 lands in Wheeler County are negligible.
[2]Source: U.S. Bureau of Census (*1969*).
[3]Sum of harvested, cultivated summerfallow, pasture or grazing, and other.
[4]Soil improvement crops, crop failures, and idle cropland.
[5]Not included in the total percentage.

Table 4.--*Land class distribution within 3 Major Land Resource Areas in eastern Oregon*

MLRA	Total area[1]	Fraction of land area[2] in --		
		Tilled cropland	Adjacent nontilled cropland	Range and forest land
	Thousands of hectares			
B7	217	0.46	0.20	0.34
B8	1268	.50	.11	.39
B9	206	.34	.18	.45
B9 (Wallowa)	252	.15	.28	.57
Overall	1943	.43	.15	.42

[1]Conservation needs inventory (CNI) estimates obtained from a 1967 inventory (Conservation Needs Inventory Committee, *1971*).

[2]Tilled cropland = Σ (soil mapping unit area x fraction tilled); adjacent nontilled cropland = Σ (1 - tilled cropland); range and forest land obtained from soil mapping units with no tilled land.

Tilled cropland (table 4) constituted about 43 percent of the total study area with a maximum of 50 percent in MLRA B8 and a low of 15 percent in B9 (Wallowa). This is the land class that will be evaluated for soil erosion by water. Adjacent nontilled cropland constitutes about 15 percent of the total land area and is used for pasture or hayland; it represents the grassland most readily improved because of its proximity to land actively cultivated.

Distribution of land in the various slope categories depended on the MLRA and land class. In MLRA B7 (fig. 3), all three land classes were distributed similarly among slope categories. Apparently, aridity, and not slope, was the major factor affecting land selection for tillable husbandry. In MLRA B8 and B9, a greater proportion of the tilled cropland fell into lower slope categories than was the case for adjacent nontilled cropland (figs. 4 and 5). Slope apparently was a major criterion for selecting lands for tillable husbandry in MLRA B8 and B9. Fortunately, for erosion control, this land was chosen for tillage husbandry before the turn of the century. Compared with the other two land classes, range and forest land had the lowest cumulative fraction in the lesser slopes. In addition to the steep slopes in the forest and rangelands of MLRA B8 and B9, shallow soil profiles, rock outcrop, and stoniness occur frequently. These are attested to by the low tolerance (T) values of erosion allowable consistent with sustained productivity (see appendix tables 2, 3, 5, and 6).

Soil erodibility factor (K) values were obtained from SCS listings for each soil type in Oregon (Billings, *1976*). These are detailed in appendix tables 1 through 6. There were large differences of K distribution among the tilled croplands within the MLRA (figs. 6 and 7). A highly erodible soil has a K value of 0.56 tonnes/ha per yr. Respective percentages of tilled cropland with $K \leq 0.37$ tonnes/ha per yr are 54, 0.5, 36, and 54 percent for MLRA B7, B8, B9, and B9 (Wallowa). Approximately 45 percent of the tilled croplands in MLRA B7 have a $K \leq 0.13$ tonnes/ha per yr. Thus, MLRA B7 has a preponderance of soils with low erodibility, whereas MLRA B8 has a preponderance of highly erosive soils. Soils of MLRA B9 are moderately erosive.

The combined rainfall and runoff erosion factor (R_T) was obtained from annual rainfall and rainfall-intensity probability-density functions as originally suggested by McCool et al. (*1976*). Detailed listings are also shown in appendix tables 1 through 6. Within MLRA B7, annual rainfall only ranges from a low value of 25 cm at the northern part to 31.2 cm in the southern part; this corresponds to an R_T of 17.4 for soils at the northerly lower elevations and an R_T of 21.3 for soils at the southerly higher elevations. These R_T were matched with soil type using soil survey maps to identify south or north position.

In MLRA B8, the R_T were apportioned linearly in the range 26.0 to 34.7 as mean annual precipitation ranged from 22.9 to 40.6 cm. The mean annual precipitation, under which a soil type is expected, was obtained as the mean of the precipitation range given in the OR-Soils-1. Whenever an occasional mean annual precipitation below 22.9 cm was given for a soil in MLRA B8, an R_T of 26.0 was arbitrarily chosen; an arbitrary choice of $R_T = 34.7$ was selected for those few soils having a mean annual precipitation greater than 40.6 cm.

In MLRA B9, exclusive of Wallowa County, R_T was apportioned linearly from

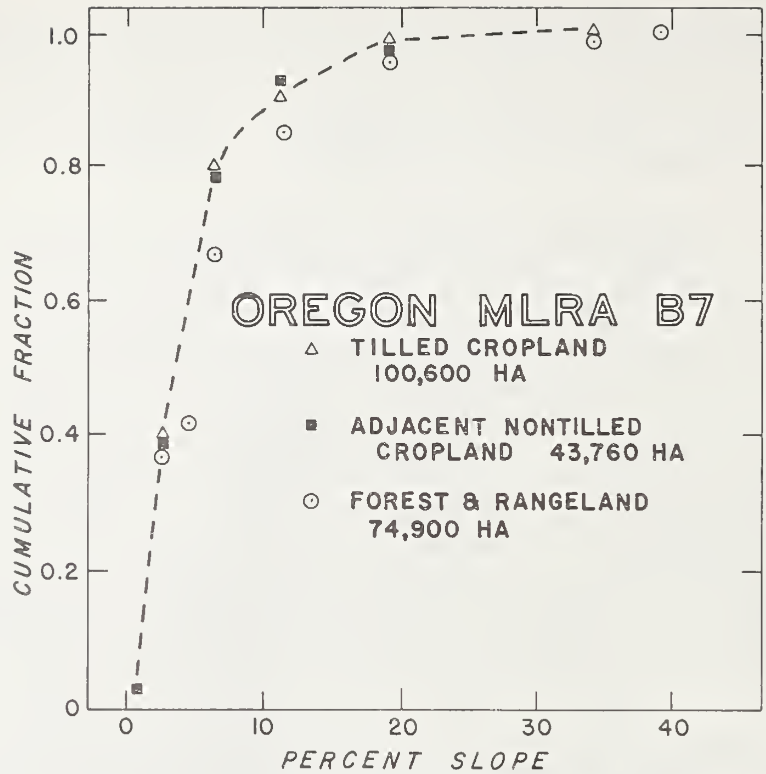


Figure 3.--Distribution of three land classes by slope steepness in Major Land Resource Area B7 in 6 northeastern Oregon counties.

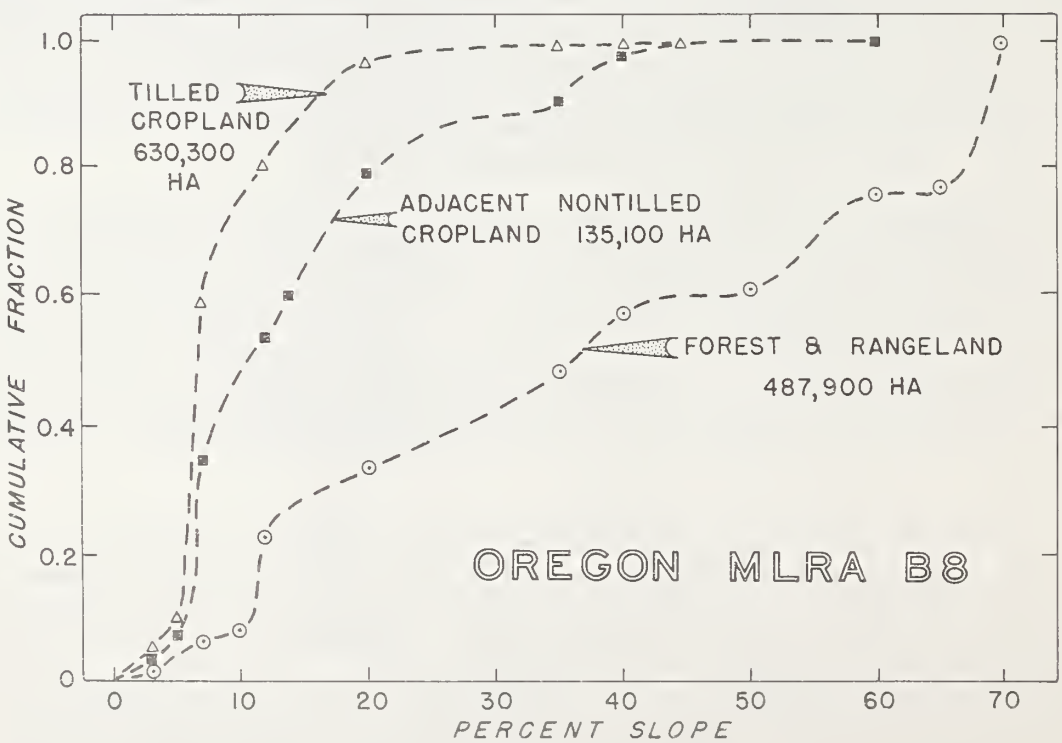


Figure 4.--Distribution of three land classes by slope steepness in Major Land Resource Area B8 in 6 northeastern Oregon counties.

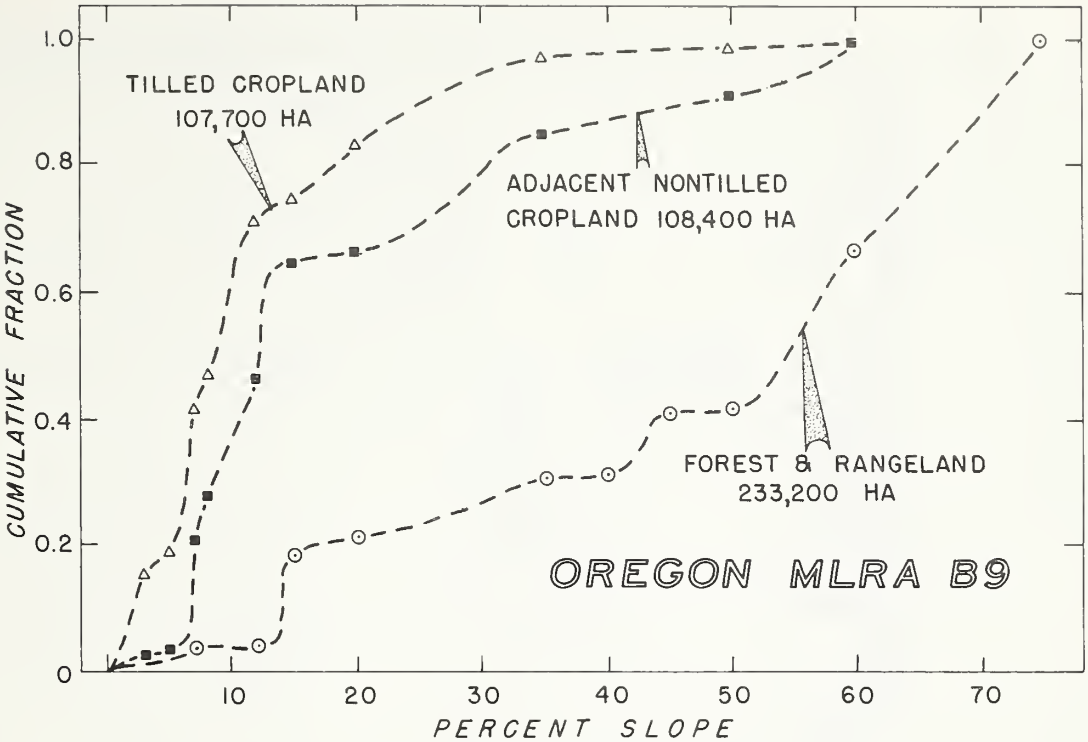


Figure 5.--Distribution of three land classes by slope steepness in Major Land Resource Area B9 in 6 northeastern Oregon counties.

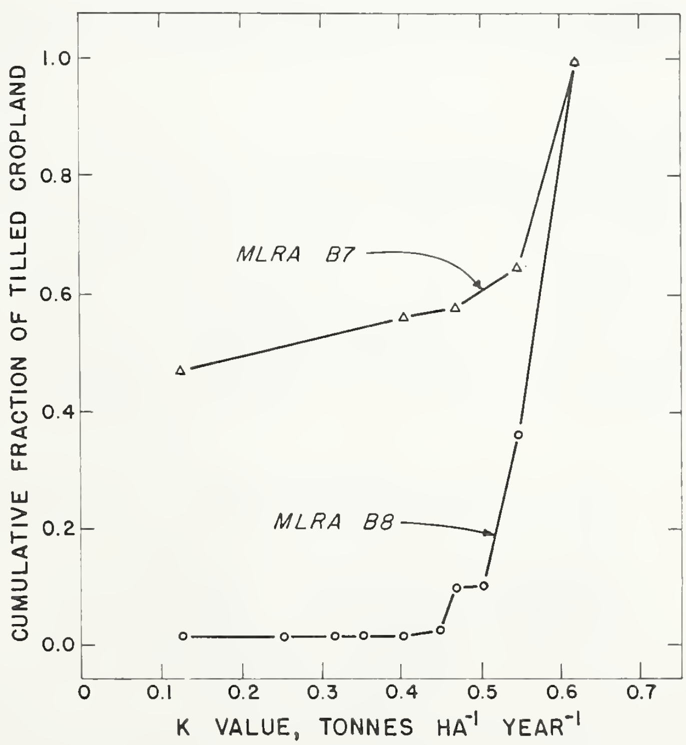


Figure 6.--Distribution of *K* value (soil erodibility factor) within tilled cropland in Major Land Resource Areas B7 and B8.

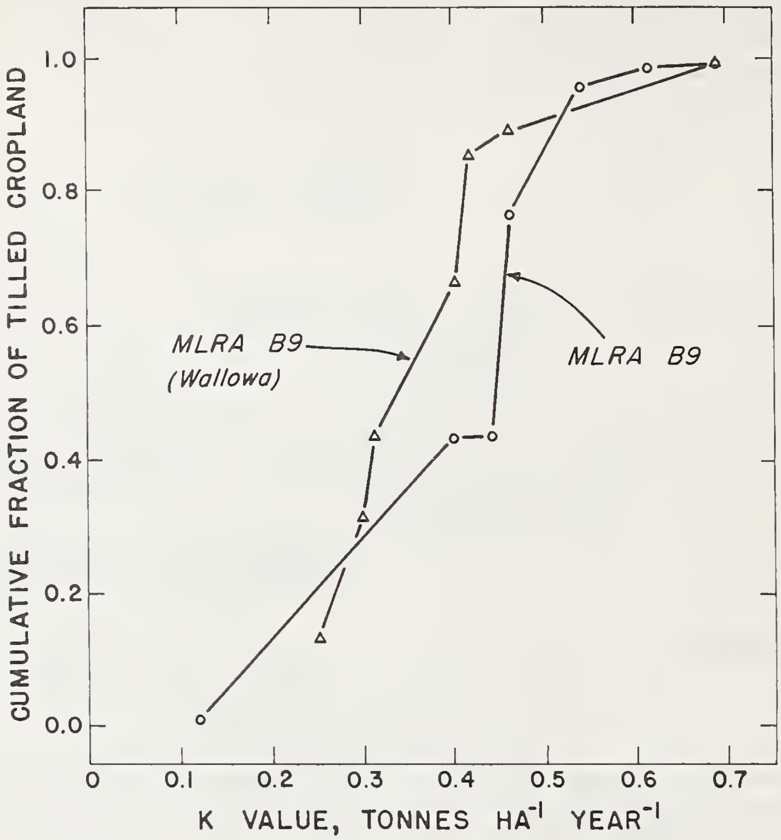


Figure 7.--Distribution of *K* value (soil erodibility factor) within tilled cropland in Major Land Resource Area B9 and B9 (Wallowa).

34.7 to 46.8 as mean annual precipitation ranged from 38.1 to 48.3 cm. Occasionally, a mean annual precipitation for a soil type in MLRA B9 was greater than 48.3 cm--in which case an R_T of 46.8 was arbitrarily chosen. Whenever mean annual precipitation for a soil type was less than 38.1 cm, the rule for MLRA B8 was used. In B9 (Wallowa), R_T was set at 34.7 because iso-R_T lines do not define a range within MLRA B9 in Wallowa County. Ranges of R_T in each MLRA are consistent with those suggested by McCool et al. (*1976*). Thus, R_T in the study area ranged from 17.4 to 46.8, which is roughly 10 percent of the moderate values observed in Central and Eastern United States (Wischmeier and Smith, *1965*).

Every soil type has a tolerance (*T*) value for soil erosion. These values were obtained from the OR-Soils-1 and are also shown in appendix tables 1 through 6. The *T* is defined as that amount of soil erosion permitted without reducing the soil productivity. Tolerance values are determined (Logan, *1977*) by depth of the rooting zone, which may be affected by root restricting layers or depth of topsoil over rock sublayers. Hydrologic groups in appendix tables 1 through 6 were also recorded for each soil type. This classification characterizes soil internal drainage ($A>B>C>D$) and is used to predict runoff. Poor internal drainage (*C* and *D*) is obviously associated with low *T* value. Internal drainage and associated runoff is therefore an important factor for erosion control in the study area.

Table 5.--*Cover and management (C) factor values depicting tillage and crop residue management alternatives in the eastern Oregon study area*

Crop sequence	Major Land Resource Area	Tillage and residue management: C value	Abbreviation	Description: Type of tillage	Residue
					Kilograms
Wheat-fallow	B7, B8, B9	0.35	X_{11}	Conventional	[1]110
		.35	X_{12}	Reduced	[2]110
		.29	X_2	--do--	[2]390
		.19	X_3	--do--	[2]840
		.10	X_4	--do--	[2]1960
Wheat-peas	B8, B9	.39	X_5	Conventional[3]	---
		[4].25	X_6	Reduced[5]	---
4 hay-2 grain	B9 (Wallowa)	.09	X_7	Conventional	([6])
Wheat-fallow	B9 (Wallowa)	.38	X_8	--do--	[7]110
		.21	X_9	--do--	[7]840
		.09	X_{10}	Reduced	[7]1960

[1]Residue (kg/ha) on surface after planting; operations after wheat harvest are moldboard plowing or disking in spring followed by 4 summer-fallow operations (cultivator with chisel points and 3 rod weeder passes) and seeding with a deep furrow drill.

[2]Same as footnote 1 except sweep or chisel was used in place of moldboard plow or disk.

[3]Fall plowing after wheat harvest with 110 kg of surface residue overwinter.

[4]Can also be used for a winter wheat-spring wheat-peas sequence with standing grain stubble overwinter (stubble amounts ranging from 255 to 560 kg/ha).

[5]No fall plowing; 560 kg standing wheat straw or 390 kg pea vines on surface overwinter. A chisel operation assumed after pea harvest and use of a split packer wheel drill that leaves 85 percent of the residue on the surface.

[6]Not specified but assumed large enough to be no problem.

[7]Tillage operations same as in footnote 1 except that disking was the primary spring tillage in X_9. Surface residue overwinter.

Factors of USLE Subject to Management

Predominant cover and management factor (*C*) values in the northeastern Oregon study area are shown in table 5. They were derived from SCS specifications for Oregon (Billings, *1976*). These factor values relate to the wheat-fallow (WF) and wheat-peas (WP) recrop sequences in MLRA B7, B8, and B9. Wallowa crop sequences are different from those of other counties because Wallowa County has a cooler climate, more suited for forage production.

In the WF system of MLRA B7, B8, and B9, the residue specification is that which is present on the ground after wheat planting; surface residue specification for the WP sequence with conventional tillage is that which is present after harvest of either crop. Separate overwinter specifications are made following each crop in the reduced tillage system of the WP sequence. Surface residue amounts in B9 (Wallowa) are also those remaining after winter wheat planting. Conventional refers to the use of a moldboard plow or disk for the primary tillage in spring; reduced refers to the use of a chisel or sweep tillage.

Published (McCalla and Army, *1961*; Papendick and Miller, *1977*; Fenster, *1977*) estimates (table 6) of surface residue reduction were used to compute harvest residue amounts needed to supply the surface residue amounts shown in table 5 for WF. Primary tillage in the conventional tillage system reduces surface residue more than that reduced by primary tillages in the reduced tillage system (table 6). Table 7 highlights the amount of harvested straw required to produce specified amounts of straw on the surface after wheat planting. Conventional moldboard tillage in spring of the fallow year is incapable of producing more than about 600 kg/ha of surface residue after the winter cereal is planted. A later discussion will amplify this point by estimating the average straw production.

Table 6.--*Typical tillage operations in wheat-fallow rotation, and associated reduction in surface residue*

Tillage system	Spring primary tillage	Tillage operations in spring of fallow year	Proportion of original residue on surface after: Tillage	Seeding
Conventional	Moldboard plow	Moldboard plow	0.15	0.074
		Chisel cultivator	.80	
		Rod weeder (3 times)	[1].73	
		Deep furrow drill	.85	
	Disk	Large disk	.50	.223
		Chisel cultivator	.80	
		Rod weeder (3 times)	[1].73	
		Deep furrow drill	.85	
Reduced	Chisel	Chisel	.75	.464
		Rod weeder (3 times)	[1].73	
		Deep furrow drill	.85	
	Sweep	Sweep	.90	.502
		Rod weeder (3 times)	[1].73	
		Deep furrow drill	.85	

[1]Three operations each leaving 0.9 of original residue on the surface, that is, $(0.90)^3 = 0.73$.

Table 7.--*Amounts of wheat or barley straw required at harvest to produce specific amounts of surface residue after seeding in wheat-fallow systems typical of Major Land Resource Areas B7, B8, and B9*

Residue on surface after fall seeding (kg/ha)	Straw yields at harvest required for indicated[1] tillage systems and spring primary tillage			
	Conventional		Reduced	
	Moldboard	Disk	Chisel	Sweep
	Kilograms per hectare			
110	1490	490	240	220
390	5270	1750	840	780
840	11350	3770	1810	1670
1960	([2])	8790	4220	3900

[1]Equivalent winter wheat yields may be estimated by assuming a straw-to-grain ratio of 1.6; winter barley yields use a 1.3 ratio; spring wheat or barley yields use a 0.8 ratio. (See table 14 for detail.)

[2]Not attainable in MLRA B7, B8, or B9.

Contour direction of tillage (a practice related to the P factor) and length of slope (L) are critical factors for water erosion control because of the large variations of slope steepness, especially in MLRA B8 and B9. Table 8 shows the combinations of L and contour tillage direction assumed in the computations of erosion in the USLE to assess the impact of these factors. An L = 213 m typifies an average slope length in a nonterraced field with field operations either on the contour ($P=f(S)$) or up- and downhill (P=1). When field operations are on the contour, the appropriate P values, ranging from 0.6 with $S < 2$ percent to 0.9 with $S > 24$ percent, are given by Wischmeier and Smith (*1965*, *1978*); however, we did not reduce or vary L to achieve values of P, as specified by Wischmeier and Smith (*1965*, *1978*), as S changes.

The assumed L = 213 m approximates an average L of 219 m obtained from 405 randomly selected cultivated field sites (table 9). The average standard error within a soil type was 37 m. Because no direct relationship was found between slope steepness and length within the Ritzville, Walla Walla, Condon, Morrow, or Quincy soil series tested in table 9, we varied S and L independently in our analyses. An L = 122 m was used to simulate a partial reduction of L produced by terracing.

Situations 5 and 6 in table 9 correspond to slope length reductions suggested by the new terrace specifications[7] proposed for Oregon. The choice of P = 1 or $P = f(S)$ typifies operations either across terraces or on the contour, respectively. Application of the terrace specifications in Oregon will likely produce some terraces amenable to crossover tillage and planting operations while others will require contour operations. Factors dictating either form are not yet clearly delineated under climatic, soil thickness, and topographic conditions in Oregon--factors much different than those in the Midwest where much research has been conducted on terrace construction and management (American Society of Agricultural Engineering, *1977*; Frevert et al., *1955*).

[7]See footnote 3.

Table 8.--*Combinations of the slope length (L) and practice factor (P) values used to simulate management of slope length and contour operations in the northeastern Oregon study area*

Situation number	*L* value	Direction of tillage: *P* value	Direction of tillage: Description
	Meters		
1	122	1	Not related to contour.
2	122	$f(S)$	Operations on contour.
3	213	1	Not related to contour.
4	213	$f(S)$	Operations on contour.
5	([1])	1	Crossover terraces.
6	([1])	$f(S)$	Operations on contour.

[1]Slope management according to terrace specification variance for Oregon where $R_T < 61$ and S = steepness of slope:

$S < 6.0$ percent ---------- $L \leq 183$ m

$6.1 < S < 12.0$ percent --- $L \leq 122$ m

$S > 12.1$ percent --------- $L \leq 76$ m

Table 9.--*Slope length characteristics for some typical soil series in the B7, B8, and B9 Major Land Resource Areas of Oregon*[1 2]

Soil type	Number of slopes measured	Maximum slope steepness (S) class in sample	Mean slope length (L)	$p(L \leq 213$ m$)$	$p(L \leq 122$ m$)$
		Percent	*Meters*		
Condon silt loam	114	36-40	251	41	18
Morrow silt loam	47	31-35	220	48	23
Quincy loamy fine sand and silt loam	49	21-25	401	28	17
Ritzville silt loam	170	36-40	153	64	41
Walla Walla silt loam	94	31-35	238	45	24
Walla Walla silt loam (coarse solum)	64	26-30	237	44	22
Walla Walla silt loam (low rainfall)	41	26-30	236	43	17

(The "Measured characteristic" heading spans the five data columns.)

[1]Data obtained from "Land Inventory Monitor" survey being conducted by Soil Conservation Service in Umatilla, Sherman, Morrow, and Gilliam Counties.

[2]The two right-hand columns show probabilities that the observed L will be less than or equal to 213 or 122 m, respectively, for columns 5 and 6.

RESIDUE PRODUCTION CHARACTERISTICS

Five-year (1971-76) estimates of crop area and production were used to estimate the amount of plant residue at harvest. These estimates of wheat and barley (*Hordeum vulgare* L.), as well as hay, are shown by county in table 10. Both harvested area and production of wheat were notably less variable among years within the 5-year period compared with those of barley. Year-to-year variations of production are greater than 25 percent for either grain crop, suggesting the same year-to-year variation in residue production. Only a negligible production of oats (*Avena sativa* L.) occurs in the study area--thus, characteristics of oats production are not included.

Table 10.--*Wheat, barley, hay, and process pea production in the 6 northeastern Oregon counties associated with Major Land Resource Areas B7, B8, and B9*[1] [2]

County	Wheat production[3]		Barley production[3]		Hay production[3]	
	Thousands of hectares	*Thousands of tonnes*	*Thousands of hectares*	*Thousands of tonnes*	*Thousands of hectares*	*Thousands of tonnes*
Gilliam	43.46	81.07	6.21	13.28	2.53	12.56
Morrow	64.26	114.70	10.01	19.82	7.20	56.35
Sherman	46.87	102.89	8.99	19.50	1.90	6.04
Umatilla	103.37	317.67	13.01	39.90	13.41	108.94
Wallowa	9.03	24.49	3.36	10.83	15.58	84.87
Wasco	29.05	81.30	4.05	11.19	7.07	39.52
Sum	296.04	722.12	45.63	114.52	47.69	308.28
Average C.V.[4]	17	25	48	55	18	17

[1] Source: Extension Service. 1972-77. Oregon Crop Commodity Data. Oregon State University, Corvallis.

[2] Process peas are produced in Umatilla County as follows:

	Mean	*CV percent*
Hectares harvested	16,216	10
Production (tonnes)	39,167	21

[3] Averaged over 5 yr, 1971-75. Estimates are from harvested area.

[4] Average coefficient of variation indicates the variation over years; average was over the 6 counties.

Hay production (table 10) is notably larger in Morrow, Umatilla, and Wallowa Counties because of irrigation. Sherman and Gilliam Counties show hay production typical of that in the dryland parts of Morrow, Umatilla, and Wallowa Counties. A typical dryland sum of hay production was obtained for Morrow, Umatilla, and Wasco Counties, assuming they had the same proportional hay production to cropland as in Sherman and Gilliam Counties. We did not include hay harvest for bioenergy, but dryland hay was a part of the tilled cropland.

Tables 11, 12 and 13 show the production characteristics of wheat, barley, and hay, respectively, for each MLRA within a county. County totals of table

Table 11.--*Mean annual wheat production in the Major Land Resource Areas B7, B8, and B9 in 6 northeastern Oregon counties*[1]

County	Annual harvested wheat in indicated MLRA			Wheat production in indicated MLRA		
	B7	B8	B9	B7	B8	B9
	----*Thousands of hectares*---			-----*Thousands of tonnes*------		
Gilliam	1.28	40.54	1.64	2.40	75.62	3.05
Morrow	10.02	49.41	4.83	17.89	88.19	8.62
Sherman	--	46.87	--	--	102.89	--
Umatilla	17.83	65.65	19.84	55.00	202.07	61.09
Wallowa	--	--	9.03	--	--	24.49
Wasco	--	28.81	--	--	81.30	--
Sum	29.13	231.28	35.34	75.29	550.07	97.25

[1]County totals apportioned to MLRA based on soil type summaries estimated cropland area (see table 2).

Note: Dashes indicate no MLRA in the county indicated.

Table 12.--*Mean annual barley production in the Major Land Resource Areas B7, B8, and B9 in 6 northeastern Oregon counties*[1]

County	Harvested barley in indicated MLRA			Barley production in indicated MLRA		
	B7	B8	B9	B7	B8	B9
	---*Thousands of hectares*---			----*Thousands of tonnes*------		
Gilliam	0.18	5.80	0.23	0.39	12.39	0.50
Morrow	1.56	7.70	.75	3.09	15.24	1.49
Sherman	--	8.99	--	--	19.50	--
Umatilla	2.25	8.26	2.50	6.89	25.34	7.67
Wallowa	--	--	3.36	--	--	10.83
Wasco	--	4.05	--	--	11.19	--
Sum	3.99	34.80	6.84	10.37	83.66	20.49

[1]County totals apportioned to MLRA based on soil type summaries estimated cropland area (see table 2).

Note: Dashes indicate no MLRA in the county indicated.

10 were apportioned to MLRA based on the proportion of tilled cropland (table 2) in a MLRA within a county. Note that the hay production figures in parentheses estimate dryland hay production in those counties with large productions of irrigated hay.

Residue production was computed from the collected statistics on the harvested portion (in tables 11 through 13) and estimated straw (or residue)-to-grain (harvested portion) ratios (table 14). Later computations used a straw-

Table 13.--*Mean annual hay production in the Major Land Resource Areas B7, B8, and B9 in 6 northeastern Oregon counties*[1]

County	Harvested hay in indicated MLRA[2]			Hay production in indicated MLRA[3]		
	B7	B8	B9	B7	B8	B9
	------*Thousands of hectares*------			--------*Thousands of tonnes*---------		
Gilliam	0.07	2.36	0.10	0.37	11.71	0.47
Morrow	1.12(0.49)	5.54(2.43)	.54(0.24)	8.79(1.99)	43.33(9.89)	4.23(0.98)
Sherman	--	1.90	--	--	6.04	--
Umatilla	2.32(0.85)	8.52(3.22)	2.58(0.95)	18.83(3.46)	69.19(13.10)	20.91(3.87)
Wallowa	--	--	15.88	--	--	84.87
Wasco	--	7.07(1.65)	--		39.52(6.72)	
Sum	3.51	25.39	18.80	27.99	169.79	110.48

[1]County totals apportioned to MLRA based on soil type summaries estimated cropland area (see table 2).

[2]Values in parentheses are estimated hectares of dryland hay assuming that hay constitutes the same fraction of the cropland as in Gilliam and Sherman Counties.

[3]Values in parentheses are estimated dryland production obtained as the product of dryland production and an average yield of 4.07 tonnes/ha in Gilliam and Sherman Counties.

Note: Dashes indicate no MLRA in the county indicated.

Table 14.--*Ratios of field residues to grain (or reported harvested portion) in the 3 major nonirrigated crops in Major Land Resource Areas B7, B8, and B9*

Crop	*Varieties*	*Straw (or residue)/grain*
Winter wheat[1]	Hyslop, Nugaines	1.60
Winter barley[1]	Kamiak, Hudson	1.31
Spring barley[1]	Steptoe, Gem	.81
Green process peas[2]	Dark Skin Perfection	1.58

[1]Source: Breeding nurseries of C. R. Rohde, Pendleton, Oreg.

[2]Rasmussen and Pumphrey (*1977*).

to-grain ratio of 1.6 for winter wheat, and 1.06 for barley. We assumed that the production areas for winter and spring barley were about equal, whereas spring wheat made up only a negligible share of the wheat production area. Projections about nutrient cycling in residues were based on the nutrient concentrations shown in table 15.

Table 15.--*Estimated N, P, K, and S concentrations in small grain and pea residues produced in the northeastern Oregon study area*

Crop residue	Nutrient concentration			
	N[1]	P[2]	K[2]	S[2]
	Percent			
Wheat straw	0.30	0.06	0.95	0.09
Barley straw	.28	.06	.90	.12
Pea vines	1.76	.09	1.53	.15

[1]Source: Rasmussen and Pumphrey (*1977*).
[2]Source: Boawn and Allmaras (*1974*).

Residue production characteristics are summarized in table 16 for each MLRA. The percentage of tilled cropland apportioned to each major crop or alternate use is shown in the last column of table 16. These estimates for the four major crops (wheat, barley, hay, and peas) are based on the harvested area shown in tables 11 and 12. The remaining area in tilled cropland (table 2) was designated as fallow.

CROP SEQUENCE DESCRIPTIONS

Soil erosion estimates were made for three crop sequences: wheat-fallow, wheat-peas, and a sequence of 2 years wheat with 4 years hay. The detailed crop sequence designations are shown in appendix tables 1, 2, and 3. For convenience, the tilled cropland totals for each sequence and MLRA are shown later (see table 24, p. 36). All of the tilled cropland of B7 was assumed to be in the WF sequence. In B8, a portion of the wheat and barley harvested area, equal to the harvested area of process peas, was assigned to the WP sequence. The remaining tilled cropland in B8 was assigned to a WF sequence. Areas for the WP or WF sequences in B9 were assigned in a manner similar to the procedure used in B8. In all three of these MLRA, hayland area was assumed to be negligible; hay was not considered as a significant crop for erosion control in either the WP or WF sequences. Two crop sequences were assumed for B9 (Wallowa): WF, or H4G2--a sequence of 2 years grain and 4 years hay. First, the area for the H4G2 sequence was determined as one-fourth of the harvested area for hay. After assignment of the required small grain harvested area to the H4G2 sequence, the remainder of the tilled cropland was designated as WF. The H4G2 sequence in Wallowa County receives supplemental irrigation, especially for the hay crop.

Table 16.--*Crop residue production (and associated nutrient content) in the northeast Oregon study area*

MLRA	Crop	Residue production			Nutrient production in residue N	P	K	S	Tilled cropland
		Hectares	*Tonnes*	*Tonnes/ha*	------------*Tonnes*-----------				*Percent*
B7	Hay	1410	5820	4.13	--	--	--	--	1.8
	Wheat	29130	75290	4.14	361	72	1144	108	37.8
	Barley	3990	10992	2.75	31	7	99	13	5.2
	Wheat and barley	33120	131456	3.97	392	79	1243	122	43.0
	Fallow	--	--	--	--	--	--	--	55.2
B8	Hay	11560	47460	4.11	--	--	--	--	1.8
	Wheat	231280	880112	3.81	2640	528	8361	792	36.6
	Barley	34800	88680	2.55	248	53	798	106	5.5
	Wheat and barley	266080	968792	3.65	2889	581	9159	898	42.2
	Peas	6623	25752	3.89	453	23	394	39	1.0
	Fallow	--	--	--	--	--	--	--	55.0
B9	Hay	1290	5320	4.12	--	--	--	--	1.9
	Wheat	26310	116416	4.42	349	70	1106	105	39.2
	Barley	3840	10240	2.94	29	6	92	12	5.2
	Wheat and barley	29790	126656	4.25	378	76	1198	117	44.3
	Peas	9292	36131	3.89	636	32	553	54	13.8
	Fallow	--	--	--	--	--	--	--	39.9
B9 (Wallowa)	Hay	15580	84870	5.45	--	--	--	--	40.5
	Wheat	9030	39184	4.34	118	24	372	35	23.5
	Barley	3360	11480	3.42	32	7	103	14	8.7
	Wheat and barley	12390	50664	4.09	150	30	476	49	32.2
	Fallow	--	--	--	--	--	--	--	27.2

Note: Dashes indicate lack of residue or nutrient produced on fallow, or no measurement of nutrient produced in hay.

There were nonuniform geographic distributions of the WP sequence within B8 and B9, and of the H4G2 sequence within B9 (Wallowa). In some instances, the distributions of crop sequences among slope classes within a MLRA were affected by this nonuniform geographic distribution of the WP sequence. Assignment of a process pea hectarage to soil mapping units in eastern Umatilla County caused only a minor difference of crop sequence distribution among slope class in B8. Eighty-two and 100 percent of the WP land area had slopes less than 12 and 20 percent, respectively. Comparative percentages for the WF land area were 80 and 93 percent. In B9, however, the slope-area relations were different for the two sequences. Fifty-one, 81, and 93 percent of the WP land area had slopes less than 7, 12, and 20 percent, respectively. Comparative percentages for the WF land area were 29, 61, and 73 percent for the same three slope classes.

Within B9 (Wallowa), the H4G2 sequence is generally confined to stream terrace positions. In our analysis, all of that sequence was assigned to soil mapping units with slopes less than 7 percent. Meanwhile, only 27 percent of the WF sequence was assigned to soil mapping units with slopes less than 7 percent.

WEIGHTED AVERAGE TOLERANCE AND WEIGHTED AVERAGE SOIL LOSSES

For a MLRA, weighted average tolerance (T_w) and weighted average soil losses (A_w) provide an overview of soil erosion control. A_w and T_w are weighted as follows:

$$A_w = (\Sigma a_i\ A_i)/\ \Sigma a_i;\ T_w = (\Sigma a_i\ T_i)/\ \Sigma a_i$$

where A_w and T_w are weighted average soil loss and soil erosion tolerance for a collection of soil mapping units each having a_i hectares. T_w values for the WF sequence ranged from 4.8 to 10.8 tonnes/ha per yr, depending on MLRA (table 17). For the WP sequence, the range was 8.5 to 11.2 tonnes/ha per yr. The maximum T_w is 11.2 tonnes/ha per yr, which indicates that a significant percentage of the soils in B9 (Wallowa), B9, and B8 have a restricted depth of rooting. The T value defines soil erosion allowable consistent with sustained soil productivity; if a soil has a rooting depth of at least 150 cm, it can sustain an annual soil loss of no more than 11.2 tonnes/ha. The T_w values (table 17) alone for the MLRA indicate that soil losses in B9 and B9 (Wallowa) must be more restrictive than in B8, which in turn must be more restrictive than in B7. Greater T_w values for the WP sequence as compared with the WF sequence within a MLRA reflect concentration of this sequence on Athena, Walla Walla, and Palouse soils, which as a group has a deeper root zone than many other soils in B8 and B9.

A_w in table 17 show a large variation in average MLRA soil loss and also in the expected management influences on soil loss. A_w in B7 were less than 40 percent of T_w even for the conventional or reduced tillage (X_{11} or X_{12}) with 110 kg/ha of residue on the surface after wheat planting; A_w for the H4G2 sequence (X) in B9 (Wallowa) were also much below the T_w of 4.5 tonnes/ha per yr. In all of the other MLRA and crop rotations, some choices of tillage, slope length, or practice factor produced A_w greater than T_w.

Table 17.--*Slope length, tillage direction, tillage and residue management, and cropping system effects on weighted average soil erosion in eastern Oregon*

Major Land Resource Area	Slope length	Practice factor	Crop sequence	Weighted average soil loss[1] for indicated tillage practice				Weighted average[2] erosion tolerance
	Meters			*Tonnes/ha per yr*				
B7			Wheat-fallow	X_{11} or X_{12}	X_2	X_3	X_4	10.8
	213	1		3.7	3.1	2.0	1.1	
	213	$f(S)$		2.6	2.1	1.4	.7	
	122	1		3.2	2.6	1.7	.9	
	122	$f(S)$		2.2	1.8	1.2	.6	
	$f(S)$	1		3.0	2.5	1.6	.9	
	$f(S)$	$f(S)$		2.1	1.7	1.1	.6	
B8			Wheat-fallow	X_{11} or X_{12}	X_2	X_3	X_4	7.9
	213	1		10.3	8.6	5.6	3.0	
	213	$f(S)$		7.3	6.1	4.0	2.1	
	122	1		8.8	7.3	4.8	2.5	
	122	$f(S)$		6.2	5.1	3.4	1.8	
	$f(S)$	1		8.4	7.0	4.6	2.4	
	$f(S)$	$f(S)$		5.8	4.8	3.2	1.7	
B9			Wheat-fallow	X_{11} or X_{12}	X_2	X_3	X_4	6.4
	213	1		22.1	18.3	12.0	6.3	
	213	$f(S)$		19.3	16.0	10.5	5.5	
	122	1		18.7	15.5	10.2	5.3	
	122	$f(S)$		16.4	13.6	8.9	4.7	
	$f(S)$	1		16.9	14.0	9.2	4.8	
	$f(S)$	$f(S)$		14.6	12.1	7.9	4.2	
B9 (Wallowa)			Wheat-fallow or (H4G2)	X_8	X_9	X_{10}	(X_7)	4.8 (4.5)
	213	1		10.3	6.2	2.7	(.5)	
	213	$f(S)$		7.6	4.6	2.0	(.3)	
	122	1		8.8	5.2	2.2	(.4)	
	122	$f(S)$		6.4	3.9	1.7	(.2)	
	$f(S)$	1		9.1	5.1	2.2	(.5)	
	$f(S)$	$f(S)$		6.5	3.6	1.6	(.2)	
B8 or (B9)			Wheat-peas	X_5	X_6	(X_5)	(X_6)	11.2 (8.5)
	213	1		15.1	9.7	(14.0)	(9.0)	
	213	$f(S)$		10.0	6.4	(10.2)	(6.6)	
	122	1		12.8	8.2	(11.9)	(7.6)	
	122	$f(S)$		8.5	5.4	(8.7)	(5.5)	
	$f(S)$	1		12.4	7.9	(11.4)	(7.3)	
	$f(S)$	$f(S)$		8.1	5.2	(8.1)	(5.2)	

[1]Symbol A_w used in text.
[2]Symbol T_w used in text.

For any of the tillage and surface residue alternatives in WF in table 17, a slope length reduction from 213 to 122 m combined with contour operation reduced A_W about 40 percent except in B9 where A_W was reduced only 25 percent. Only in B9 does a variable slope length ($L=f(S)$) significantly reduce A_W below that for a slope length of 122 m. A slope length of 122 m typifies a partial reduction of slope length by terracing, but a variable slope length ($L=f(S)$) fulfills the new terrace standards for Oregon (table 8). An examination of soil erosion versus slope steepness that amplifies effectiveness of ($L=f(S)$) in B9 appears in the next section.

Reductions of A_W (table 17) by tillage and surface residue alternatives for a given slope length and contouring practice are proportional to their respective C values shown in table 5. In the WF sequence, A_W can be reduced more by choice of surface residue management than by combined terracing and contour operations; however, in the WP sequence, reductions of A_W are about the same with tillage and residue management as with combined terracing and contouring. Contour operation is somewhat more effective than slope length reduction for reducing A_W in B9 (Wallowa), B8, and B7, but less effective in the WF sequence in B9. This observation should encourage contour operation because it would generally cost less than terracing.

FRACTION OF CROPLAND WITH LOSSES LESS THAN TOLERANCE

Conventional or reduced tillage with only 110 kg/ha of residue on the soil surface after planting (or overwinter) in the WF sequence (table 18) provided 88 percent of cropland in B7 with soil losses (A) less than T; similar tillage and residue management in B9 and B9 (Wallowa) provided only 25 and 16 percent of the cropland with $A < T$. These percentages pertain to 213-m slope lengths combined with up-down-hill tillage and planting operation. The most aggressive management for soil erosion control in the WF sequence, that is, reduced tillage with 1960 kg/ha surface residue and contour operation on terraced fields, is projected to reduce A below T on all the tilled cropland in B7; but this same maximum management input in B8, B9, and B9 (Wallowa) cannot keep A below T on 3, 26, and 2 percent of the tilled cropland in the WF sequence. In the WP sequence, the fall primary tillage alternative can maintain only 37 and 48 percent of the tilled cropland with $A < T$; this tillage alternative does poorly (82 and 62 percent with $A < T$, respectively, for B8 and B9) even with the most aggressive contour operation and terracing combination.

Again, as with A_W discussed earlier, the surface residue management alternative is relatively more effective for soil loss control than combined management of slope length and contour operation in the WF sequence. Both types of management are about equally effective in the WP sequence. Table 18 also shows that, with 1960 kg/ha of residue on the surface after wheat planting or overwinter, the combined slope length reduction and tillage direction alternatives have little effect on the percentage of tilled cropland with $A < T$. This is a dramatic indication of the effectiveness of surface residue management to control soil erosion.

Soil erosion was completely controlled below T in the H4G2 sequence in B9 (Wallowa). Thus, there was adequate soil erosion control for all slopes and

soil types even though T_W for this sequence was only 4.5 tonnes/ha per yr (table 17).

Information in tables 17 and 18 shows that tillage and residue management can be used in combination with contour operation and terracing to achieve soil erosion control. Analysis of the slope steepness effect on the percentage of

Table 18.--*Percentage of tillable cropland in the eastern Oregon study area with soil erosion losses below tolerance, as affected by tillage and residue handling system, slope length change, and tillage direction*

Major Land Resource Area	Slope length	Practice factor	Cropland with $A < T$ with indicated tillage practice and cropping sequence[1]					
			Wheat-fallow				Wheat-pea	
	Meters		*Percent*					
B7			X_{11} or X_{12}	X_2	X_3	X_4		
	213	1	88	88	100	100		
	213	$f(S)$	90	94	100	100		
	122	1	88	93	100	100		
	122	$f(S)$	94	100	100	100		
	$f(S)$	1	88	93	100	100		
	$f(S)$	$f(S)$	94	100	100	100		
B8			X_{11} or X_{12}	X_2	X_3	X_4	X_5	X_6
	213	1	55	62	72	91	37	82
	213	$f(S)$	66	70	87	93	82	82
	122	1	62	65	81	93	37	82
	122	$f(S)$	68	78	89	96	82	82
	$f(S)$	1	59	68	82	94	37	82
	$f(S)$	$f(S)$	71	79	90	97	82	82
B9			X_{11} or X_{12}	X_2	X_3	X_4	X_5	X_6
	213	1	25	32	37	66	48	56
	213	$f(S)$	37	37	61	66	62	63
	122	1	29	33	40	66	48	62
	122	$f(S)$	37	40	66	73	62	81
	$f(S)$	1	25	33	44	66	48	62
	$f(S)$	$f(S)$	37	40	66	74	62	88
B9 (Wallowa)			X_8	X_9	X_{10}	X_7 (H4G2)		
	213	1	16	28	86	100		
	213	$f(S)$	49	75	92	100		
	122	1	17	49	86	100		
	122	$f(S)$	75	86	92	100		
	$f(S)$	1	16	32	93	100		
	$f(S)$	$f(S)$	49	86	98	100		

[1] A is soil erosion and T is tolerance value for soil erosion.

tilled cropland (in the slope category) with $A < T$ provides an elementary understanding of how best to reduce soil erosion on a field that contains a known collection of soil mapping units detailed enough to distinguish slope phase. The detailed information is given in tables 19, 20, 21, and 22. Figures 8 and 9 summarize for WF in B8 and B9 the maximum effects of the three managements either alone or in combination.

Table 19.--*Slope effects on tilled cropland in Major Land Resource Areas B7, B8, and B9 with soil losses less than tolerance as affected by tillage and residue management and contour operation in wheat-fallow with 213-m slope length*

Major Land Resource Area	Slope[1]	Fraction of MLRA tilled cropland	Tilled cropland with $A < T$ with indicated contour operation, and tillage and residue management							
			Up-down-hill				Contour operation			
			X_{11} or X_{12}	X_2	X_3	X_4	X_{11} or X_{12}	X_2	X_3	X_4
	Percent		*Percent*							
B7	0-3	0.42	100	100	100	100	100	100	100	100
	3-7	.35	100	100	100	100	100	100	100	100
	7-12	.11	85	85	100	100	100	100	100	100
	10-20	.12	15	15	100	100	15	100	100	100
	20-35	.01	0	0	0	100	0	0	0	100
B8	0-4	.10	100	100	100	100	100	100	100	100
	2-7	.49	91	98	98	100	98	98	100	100
	7-12	.21	1	17	41	95	33	50	95	95
	10-20	.16	1	1	31	71	1	5	46	81
	19-33	.03	1	1	1	1	3	3	3	21
	24-41	.01	0	0	0	0	0	0	0	0
B9	0-3	.09	100	100	100	100	100	100	100	100
	3-7	.26	80	98	98	100	98	98	100	100
	7-12	.32	0	12	26	100	26	26	100	100
	12-20	.12	0	0	0	38	0	0	0	38
	20-35	.20	0	0	0	0	0	0	0	0
	35-60	.02	0	0	0	0	0	0	0	0
B9 (Wallowa)			X_8	X_9	X_{10}		X_8	X_9	X_{10}	
	0-3	.29	--	--	--		--	--	--	
	2-9	.64	18	32	93		56	85	100	
	15-30	.03	0	0	74		0	0	74	
	30-50	.04	0	0	0		0	0	0	

[1]Slope classes obtained by grouping the original listing and computing upper or lower limits weighted by area in the slope class.

Note: Dashes indicate no land with slopes in 0-3 class.

With no reduction of slope length (L=213 m), tillage with large amounts of surface residue (X_4) along with contour operation ($P=f(S)$) can maintain soil erosion losses below T on at least 95 percent of the tilled cropland with slopes < 12 percent in B8 (fig. 8). Table 19 shows that 80 percent of B8 tilled cropland has slopes < 12 percent. When only small amounts of surface residue (X_{11} or X_{12}) are used, soil erosion can be kept below T on 90 percent of the tilled

Table 20.--*Slope effects on tilled cropland in Major Land Resource Areas B7, B8, and B9 with soil losses less than tolerance as affected by tillage and residue management and contour operation in wheat-fallow with 122-m slope length*

Major Land Resource Area	Slope[1]	Fraction of MLRA tilled cropland	Tilled cropland with $A < T$ with indicated contour operation, and tillage and residue management							
			Up-down-hill				Contour operation			
			X_{11} or X_{12}	X_2	X_3	X_4	X_{11} or X_{12}	X_2	X_3	X_4
	Percent		------Percent------							
B7	0-3	0.42	100	100	100	100	100	100	100	100
	3-7	.35	100	100	100	100	100	100	100	100
	7-12	.11	85	85	100	100	100	100	100	100
	10-20	.12	15	55	100	100	55	100	100	100
	20-35	.01	0	0	0	100	0	0	0	100
B8	0-4	.10	100	100	100	100	100	100	100	100
	2-7	.49	98	98	98	100	98	100	100	100
	7-12	.21	17	32	71	95	46	74	95	100
	10-20	.16	1	1	46	81	1	20	60	96
	19-33	.03	3	3	3	21	3	3	6	21
	24-41	.01	0	0	0	0	0	0	0	0
B9	0-3	.09	100	100	100	100	100	100	100	100
	3-7	.26	98	98	98	100	98	100	100	100
	7-12	.32	0	13	35	100	26	35	100	100
	12-20	.12	0	0	0	38	0	0	38	100
	20-35	.20	0	0	0	0	0	0	0	0
	35-60	.02	0	0	0	0	0	0	0	0
B9 (Wallowa)			X_8	X_9	X_{10}		X_8	X_9	X_{10}	
	0-3	.29	--	--	--		--	--	--	
	2-9	.64	19	56	93		85	93	100	
	15-30	.03	0	0	74		0	74	74	
	30-50	.04	0	0	0		0	0	0	

[1]Slope classes obtained by grouping the original listing and computing upper or lower limits weighted by area in the slope class.

Note: Dashes indicate no land with slopes in 0-3 class.

cropland with slopes < 7 percent. This comparison points out the need for using more surface residues on the 7- to 12-percent slopes to control erosion. Further comparison of the percent cropland with $A < T$ for the reduced (L=122 m) slope length versus that for L=213 m (fig. 8) shows contouring or terracing does not fully substitute for surface residue in the 7- to 12-percent slope range.

Text continues on page 32.

Table 21.--*Slope effects on tilled cropland in Major Land Resource Areas B7, B8, and B9 with soil losses less than tolerance as affected by tillage and residue management and contour operation in wheat-fallow with slope length conforming to the terrace specification for Oregon*

Major Land Resource Area	Slope[1]	Fraction of MLRA tilled cropland	Tilled cropland with $A < T$ with indicated contour operation, and tillage and residue management							
			Up-down-hill				Contour operation			
			X_{11} or X_{12}	X_2	X_3	X_4	X_{11} or X_{12}	X_2	X_3	X_4
	Percent		Percent							
B7	0-3	0.42	100	100	100	100	100	100	100	100
	3-7	.35	100	100	100	100	100	100	100	100
	7-12	.11	85	85	100	100	100	100	100	100
	10-20	.12	15	55	100	100	55	100	100	100
	20-35	.01	0	0	0	100	0	0	0	100
B8	0-4	.10	100	100	100	100	100	100	100	100
	2-7	.49	92	98	98	100	98	98	100	100
	7-12	.21	17	32	71	95	46	74	95	100
	10-20	.16	1	18	53	86	20	33	69	99
	19-33	.03	3	3	6	26	3	3	6	26
	24-41	.01	0	0	0	0	0	0	0	0
B9	0-3	.09	100	100	100	100	100	100	100	100
	3-7	.26	80	98	98	100	98	100	100	100
	7-12	.32	0	12	35	100	26	98	100	100
	12-20	.12	0	0	38	38	0	35	38	100
	20-35	.20	0	0	0	2	0	0	0	2
	35-60	.02	0	0	0	0	0	0	0	0
B9 (Wallowa)			X_8	X_9	X_{10}		X_8	X_9	X_{10}	
	0-3	.29	--	--	--		--	--	--	
	2-9	.64	18	32	93		56	93	100	
	15-30	.03	0	74	74		0	74	74	
	30-50	.04	0	0	97		0	0	97	

[1] Slope classes obtained by grouping the original listing and computing upper or lower limits weighted by area in the slope class.

Note: Dashes indicate no land with slopes in 0-3 class.

Table 22.--*Slope effects on tilled cropland in Major Land Resource Areas B8 and B9 with soil losses less than tolerance as affected by tillage and residue management, contour operation, and slope length in the wheat-pea sequence*

Major Land Resource Area	Slope	Fraction of MLRA tilled cropland	Tilled cropland with $A < T$ within indicated slope length, contour operation, and tillage-residue management											
			213 m				122 m				$f(S)$			
			Up-down-hill		Contour		Up-down-hill		Contour		Up-down-hill		Contour	
			X_5	X_6	X_5	X_6	X_5	X_6	X_5	X_6	X_5	X_6	X_5	X_6
	Percent		*Percent*											
B8	0-4	0.10	100	100	100	100	100	100	100	100	100	100	100	100
	2-7	.49	100	100	100	100	100	100	100	100	100	100	100	100
	7-12	.21	100	0	100	100	100	0	100	100	100	0	100	100
	10-20	.16	0	0	0	0	0	0	0	0	0	0	0	0
	19-33	.03	--	--	--	--	--	--	--	--	--	--	--	--
	24-41	.01	--	--	--	--	--	--	--	--	--	--	--	--
B9	0-3	.09	100	100	100	100	100	100	100	100	100	100	100	100
	3-7	.26	98	92	100	98	98	92	100	98	98	92	100	98
	7-12	.32	19	0	39	39	40	0	100	39	40	0	100	40
	12-20	.12	0	0	0	0	0	0	0	0	0	0	57	0
	20-35	.20	0	0	0	0	0	0	0	0	0	0	0	0
	35-60	.02	--	--	--	--	--	--	--	--	--	--	--	--

Note: Dashes indicate no land in the slope class.

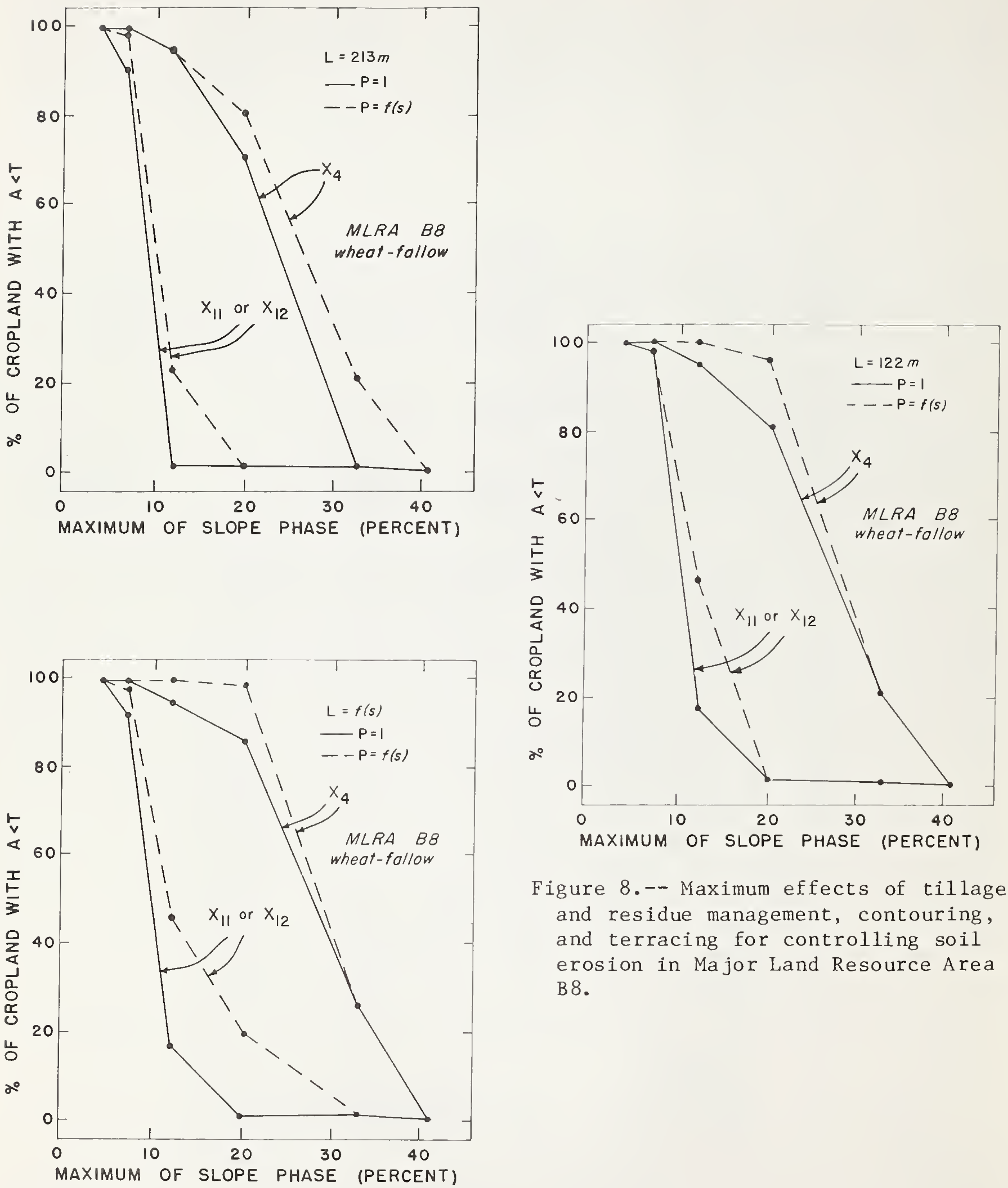
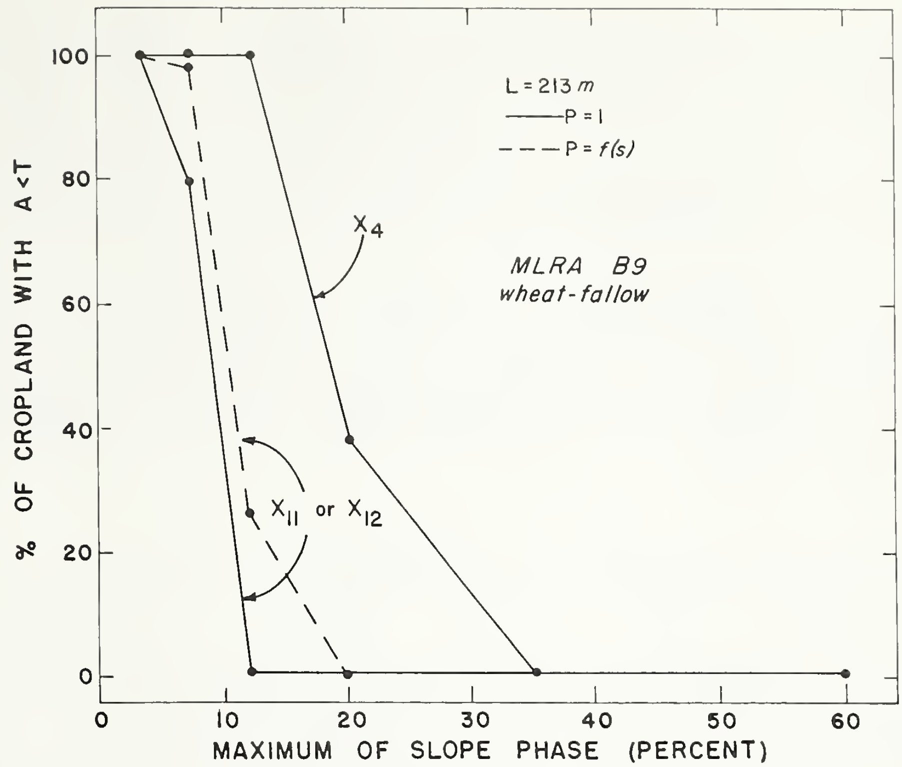


Figure 8.-- Maximum effects of tillage and residue management, contouring, and terracing for controlling soil erosion in Major Land Resource Area B8.



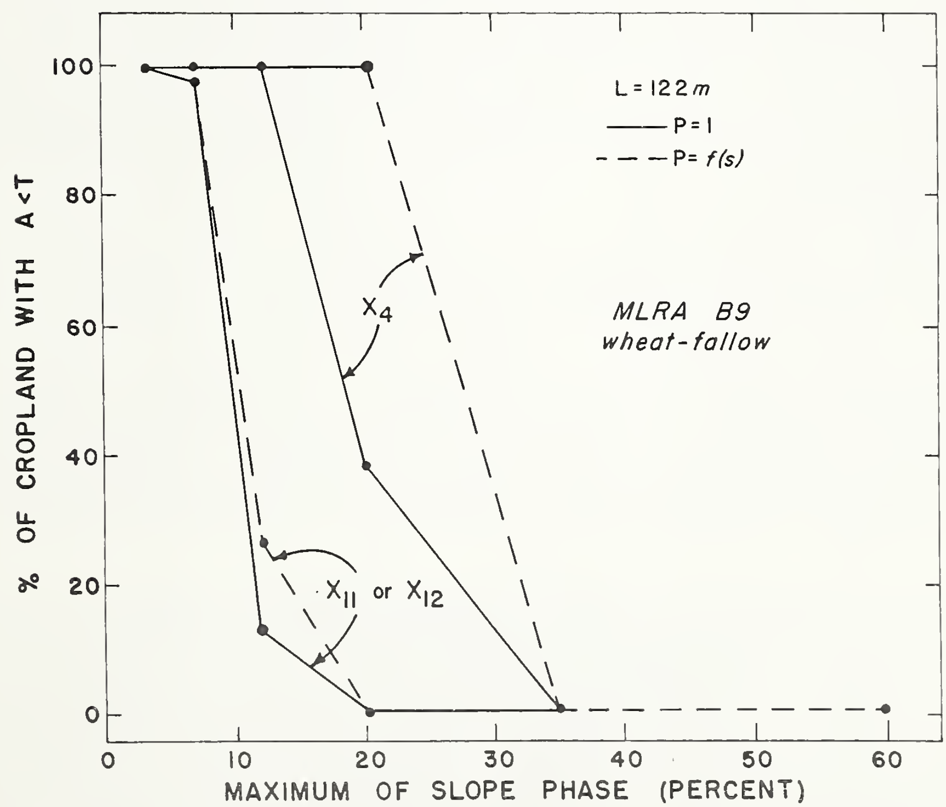


Figure 9.--Maximum effects of tillage and residue management, contouring, and terracing for controlling soil erosion in Major Land Resource Area B9.

In the 12- to 20-percent slope range, figure 8 shows that all three managements must be used and that terracing and contouring cannot replace the use of surface residues to control erosion in this slope class. Fortunately, only 16 percent of the tilled cropland of B8 is in this slope class. Only 25 percent of the tilled cropland with 20- to 33-percent slopes can be maintained with soil erosion below T, even with maximum input of all three managements; namely, tillage and residue management X_4, $L=f(S)$, and $P=f(S)$. Fortunately, the 20- to 41-percent slope class constitutes only 4 percent of the tilled cropland.

Figure 8 only shows effects of the limiting surface residue managements (X_{12} versus X_4). Tables 19, 20, and 21 show that good control (95 percent with $A < T$) of soil erosion can be attained with X_3 for slopes < 12 percent in B8 so long as contour operation is used. The surface residue for X_3 is only 840 kg/ha per yr compared with 1960 kg/ha per yr for X_4. When up-down-hill tillage is used rather than contour operation or slopes are > 12 percent, X_3 becomes notably inferior to X_4.

Analyses for the WF sequence in B9 compared with B8 show that slope-length reduction and larger amounts of surface residue are required to provide the same erosion control. Moreover, a larger fraction of tilled cropland (0.34) is in the > 12-percent slope category in B9. B8 had only 0.20 of its tilled cropland with slopes > 12 percent. Slope-length reduction (fig. 9) has a greater influence on reducing soil erosion in B9 than in B8. With L=213 m, use of the largest amount of surface residue (X_4) was ineffective for soil erosion control on slopes > 12 percent; uses of smaller amounts of surface residue were ineffective for any slope > 7 percent. When L was reduced to 122 m, the X_4 treatment along with contour operation was projected to give full control (fig. 9) for slopes up to 20 percent -- a result similar to that in B8. Compared with the X_4 treatment, the smaller amounts of surface residue were less effective for erosion control in B9 than B8 (tables 19, 20, and 21). Figure 9 only compares L=213 and 122 m, because erosion control for $L=f(S)$ was nearly identical to that for L=122 m.

To summarize for the WF sequence in B8 and B9, tillage and residue management alone can be used to control erosion on slopes ⩽ 7 percent, but contouring can be used along with lower amounts of surface residue to achieve control. In the 7- to 12-percent slope class, larger amounts of surface residue were needed than in the < 7-percent class. When slopes are > 12 percent and < 20 percent, all three forms of control are needed: tillage and residue management along with contouring and reduced slope length. At slopes > 20 percent, erosion control was poor irrespective of management input. B9 in general required larger amounts of surface residue and more reduced slope length to achieve the same control as in B8.

Soil erosion control in the WF sequence in B9 (Wallowa) was adequate for slopes below 9 percent when large amounts of residue (> 840 kg/ha) are maintained on the surface overwinter and contouring is used (tables 19, 20, 21). Again, low amounts of surface residue without contouring provided inadequate soil erosion control. Slope-length reduction (L=122 m or $L=f(S)$) provided moderate soil erosion control on the 15- to 30-percent slopes only when accompanied with contouring and surface residues greater than 840 kg/ha standing overwinter. Thus, soil erosion control in B9 (Wallowa) agrees with that in B8 and B9 in the WF sequence.

In the WP sequence, no combination of tillage and residue management with contouring and terracing provided soil erosion control on slopes > 12 percent in B8. Only tillage and residue treatment X_5 along with contouring and the full Oregon terrace specification gave any soil erosion control in the 12- to 20-percent slope class in B9. Tillage and residue treatment X_5 on 7- to 12-percent slopes in B9 did not provide more than 40 percent of the tilled cropland with $A < T$; this occurred even with combined terracing and contouring. In B8, this same X_5 treatment provided soil erosion control on the 7- to 12- percent slopes only when accompanied by contour operation. For slopes < 7 percent, nearly complete soil erosion control was achieved even with the X_5 tillage and residue treatment alone. Thus, tables 19, 20, 21, and 22 show that soil erosion control is more difficult in the WP rotation than in the WF rotation, especially in the 12- to 20-percent slope class.

CROP RESIDUE FOR OFF-SITE USE

Table 23 gives crop residue amounts available for offsite uses, such as animal feeding or bioenergy harvest. Amounts available depend on the combination of tillage and residue management, as well as combinations of slope length and contour operation. Available residue was computed assuming that the least amount of surface residue would be used to control erosion (see table 5). For example, the "red." tillage choice in table 23 for B7, B8, and B9 in WF would use tillage and residue management X_{12} so long as it gave $A < T$. When X_{12} would not keep A less than T, the residue yield from X_2 was then computed so long as it produced A less than T. The choices between X_2 and X_3 and between X_3 and X_4 resembled that between X_{12} and X_2. The "conv." tillage choice was the same as the "red." in B7, B8, and B9 except that X_{11}, using a conventional moldboard or disk operation, was used instead of X_{12}, a form of reduced tillage. The choice of tillage and residue management in B9 (Wallowa) was X_8 whenever it would keep $A < T$, X_9 when X_8 would not keep $A < T$, and finally X_{10} when X_9 would not keep $A < T$.

In the WP sequences of B8 and B9, fall primary tillage (X_5 the conventional operation) was used when it would provide $A < T$, otherwise spring primary tillage (X_6) was used to compute available residue. When the tillage and residue management treatment (table 5) with the lowest C value in a crop sequence and MLRA would not provide $A < T$, then no residue harvest was computed.

The amounts of available residue in table 23 account for the fact that harvested area for wheat and barley (table 16) was not as great as that for fallow land. This occurred in B7 because all tilled cropland (table 2) was assumed to be in the WF sequence, whereas tables 11 and 12 gave independent estimates of harvested wheat and barley, respectively. In B8, a portion of the harvested wheat and barley equal to the harvested pea area was ascribed to the WP sequence, and the remaining wheat and barley area was ascribed to the WF sequence. Even then, the harvested area in the WF sequence was less than the fallow area. A similar result occurred in B9. In the WF sequence, the alternate crop-fallow was also taken into account for computation of available residue.

Table 23.--*Crop residue available for bioenergy or animal harvest in the 6-county northeast Oregon study area as affected by practices to control water erosion in Major Land Resource Areas*

MLRA crop sequence and crop[2]	Amount harvested	Amount produced	Tillage choice	Residue available for harvest when indicated,[1] slope length, in meters, and contouring combination is used					
				122,1	122,*f*(*S*)	213,1	213,*f*(*S*)	*f*(*S*),1	*f*(*S*),*f*(*S*)
	Thousands of hectares	*Thousands of tonnes*		*Thousands of tonnes*					
B7, WF, wheat and barley	33.1	131.5	red.[3]	104.2	108.4	102.5	105.2	104.3	108.4
			conv.[3]	77.5	79.7	75.8	78.0	77.6	79.7
B8, WF, wheat and barley	259.5	944.7	red.	547.3	649.1	499.0	597.1	553.2	633.2
			conv.	401.4	489.2	369.6	443.4	514.3	465.9
B9, WF, wheat and barley	20.5	87.2	red.	25.9	38.1	24.3	35.7	27.0	38.0
			conv.	20.5	31.1	19.6	28.7	22.3	31.1
B9 (Wallowa), WF, wheat and barley	7.4	30.2	comb.[4]	9.8	19.2	6.0	16.0	6.7	18.1
B9 (Wallowa), H4G2 wheat and barley	5.0	20.4	complete[5]	20.5	20.5	20.5	20.5	20.5	20.5
B8, WP, wheat and barley	6.6	24.1	*F* and *S*[6]	16.5	15.9	16.5	15.9	16.5	15.9
B8, WP, peas	6.6	25.8	*F* and *S*	20.1	21.2	20.1	21.2	20.1	21.2
B9, WP, wheat and barley	9.3	39.5	*F* and *S*	20.6	26.9	18.5	20.6	20.6	29.1
B9, WP, peas	9.3	36.1	*F* and *S*	22.0	28.7	20.0	22.7	22.0	30.8

[1] Key to slope length and contour operation given in table 8.
[2] WF, wheat-fallow; WP, wheat-pea. Wheat and barley were considered together.
[3] "Reduced" (red.) tillage combination considered in B7, B8, and B9 is X_{12}, X_2, X_3, X_4. Conventional (conv.) tillage combination considered in B7, B8, and B9 is X_{11}, X_2, X_3, X_4.
[4] Combination (comb.) is consideration of X_8, X_9, X_{10}.
[5] Complete harvest of wheat and barley straw.
[6] Fall tillage (*F*) preferred over spring tillage (*S*) when erosion control can be achieved with fall tillage.

For the WF sequence, it was assumed that decomposition caused a 25 percent loss of residue weight per year when placed on the surface.[9] In the other sequences, no decompositional weight losses were assumed since their surface residue amounts were specified within several months after harvest.

Generally, the best inputs of slope length reduction and contouring, compared to a 213-m slope length with up-down-hill tillage, increased the available residue only about 20 percent (table 23). In the WF sequence in B7, the available crop residue ranged from 58 to 82 percent of the 131,500 tonnes produced. Comparable percentages in B8 were 39 to 69; in B9 they were 22 to 44 percent. There was notably less residue available if the "conv." (X_{11}, spring moldboarding or disking) tillage was used instead of the reduced (red., X_{12}) form of spring primary tillage. This relates to the greater incorporation of residue with moldboard plowing or disking (table 6). The WF sequence in B9 (Wallowa) could provide between 20 and 63 percent of the harvested 30,200 tonnes of residue. Available cereal residue harvests in the WP sequence, in B8 and B9, ranged from 66 to 68 and from 47 to 74 percent of the harvested production, respectively. The insensitivity to slope length and contouring managements in B8 results from their substitution to allow more conventional tillage, which in turn would yield less residue than the reduced tillage alternative. The overall test area maximum and minimum percentage of harvested residue available ranged from 49 to 70 percent in the WF sequence.

The proportion of the harvested area that can have residue harvest for animal or bioenergy use ranged from a maximum of 98 percent in the WF sequence in B9 (Wallowa) to a minimum of 62 percent in the same sequence in B9 (table 24). The two combinations of slope length and contouring in table 24 represent the extremes of available residue. The WF sequence in B7 could have a harvest on 91 percent of the harvested area. Concentrations of available residue ranged from 0.8 to 2.6 tonnes/ha in the WF sequence. Although the area for residue harvest was somewhat insensitive to slope length and contouring combination, the concentrations of residue available for harvest were sensitive, especially in B9 and B9 (Wallowa).

Information in tables 4, 23, and 24 can be used to compute the concentration characteristics of the residue. Consider the cereal residue in B8 with minimum tillage, reduced slope length ($L=f(S)$), and contouring ($P=f(S)$) as an example. The mean residue concentration on those areas which can yield residue is 2.81 tonnes/ha; the residue concentration on a harvested area basis is 2.44 tonnes/ha; on a tilled cropland basis it is 1.00 tonne/ha; on a total land area in MLRA the concentration is 0.50 tonnes/ha. These concentrations would each have economic impacts on harvest considerations for bioenergy use. They also dramatize the scattering of harvested land within B8, yet the straw yields of 4.20 tonnes/ha are above the national average.

The crop nutritional consequences of residue removal or incorporation can be evaluated from information in tables 16, 23, and 24. For example, the potential nitrogen returned in straw in B7 is about 12 kg/ha (table 16), whereas the average N fertilization for dryland wheat may be as great as 60 kg/ha.

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[9] C. L. Douglas, Jr. Unpublished manuscript. Columbia Plateau Conservation Research Center, Pendleton, Oreg. 97801.

Table 24.--*Area from which crop residue is available for bioenergy or animal harvest consistent with water erosion control in Major Land Resource Areas in the 6-county northeast Oregon study area*[1]

MLRA crop sequence and crop[3]	Total harvested area	Available residue for indicated *L* and *P* combination[2]				Total tilled cropland
		L=213 m, *P*=1		*L*=*f*(*S*), *P*=*f*(*S*)		
		Area for harvest	Mean[4] yield	Area for harvest	Mean[4] yield	
	Thousands of -----hectares-----		*Tonnes/ ha*	*Thousands of hectares*	*Tonnes/ ha*	*Thousands of hectares*
B7, WF, wheat and barley	33.1	30.0	2.5	30.1	2.6	77.2
B8, WF, wheat and barley	259.5	209.9	1.8	225.1	2.1	618.4
B9, WF, wheat and barley	20.5	12.2	1.6	13.7	2.3	48.7
B9 (Wallowa), wheat and barley	7.4	7.1	.8	[5]7.4	2.4	23.4
B9 (Wallowa), H4G2 wheat and barley	5.0	5.0	4.1	5.0	4.1	15.1
B8, WP, wheat and barley	6.6	5.5	3.0	5.5	2.9	13.3
B8, WP, peas	6.6	5.5	3.6	5.5	3.8	
B9, WP, wheat and barley	9.3	5.2	3.6	5.8	5.0	18.6
B9, WP, peas	9.3	5.2	3.8	5.8	5.3	

[1]Assumed use of "conventional" tillage whenever it would maintain $A < T$. Available residue is that harvestable consistent with water erosion control below the tolerance value.

[2]*L* is slope length, *P* is contour practice.

[3]WF, wheat-fallow; WP, wheat-pea. Wheat and barley considered together.

[4]Total available residue for harvest given in table 23.

[5]Estimated at 100 percent of harvested area.

Note also that sulfur return would only be 3.6 kg/ha, and that *S* fertilization is required in most of the dryland wheat of the Pacific Northwest. The *N* and S concentrations in cereal residues (table 15) are unusually low, yet the cereal residues are a major factor in managing the *N* and *S* fertility of dryland wheat (Ramig et al., *1975*; Rasmussen et al., *1975*).

Holt (*1979*) elaborated on the crop nutritional losses in the eroded soil as weighed against that produced in the residue. This was done for tillage and residue managements X_1 and X_4 in the WF sequence as well as X_5 and X_6 in the WP sequence. From this analysis, he shows that WF in MLRA B8 and B9 has a high nutrient loss as compared with MLRA in the midwestern or southeastern United States.

CONCLUSIONS AND SUMMARY

Soil erosion projections in this study are based on the USLE for which factor estimates were derived using empirical relations reviewed by Wischmeier and Smith (*1978*). These factor estimates for Oregon are new since 1974 and have not been tested as thoroughly as in agricultural areas east of the Rocky Mountains, where the USLE has been used since about 1960. For this reason, our soil erosion estimates could contain biases that would be discovered and corrected only by many field checks comparing predicted versus measured soil erosion. These evaluations are complex and time consuming, but they are being made at several locations in the Pacific Northwest. Even with some possible biases in our projections of soil erosion, our use of existing information provided valuable guidelines for describing the status and management of erosion in the northeastern Oregon dryland agriculture.

Our projections repeatedly revealed that water erosion control can be attained by a choice of managements in a conservation system. This information also supports a field specific approach in which sediment control can be achieved with many different practices. On slopes of less than 12 percent, there is leeway to use tillage and residue management alone for erosion control or to use tillage and residue management in combination with contouring operations. Control would generally be effective without terracing to reduce slope length. Slopes of 12 to 20 percent require that all three alternatives be used and that greater amounts of surface residue are necessary. Where slopes are greater than 20 percent, it will be difficult to maintain soil erosion below tolerance in WF or WP sequences.

The estimated soil erosion differed among MLRA. Each MLRA has a particular combination of soils, climate, topography, and crop sequence. Our studies utilized this resource information and projected a difference of erosion characteristics among MLRA. For example, if the weighted soil loss for B7 was 1, then that for B8 and B9 were 2.7 and 5.8, respectively. B8 and, especially, B9, have much more severe potential for soil erosion; the potential is much greater than expected on the basis of the relative R_T values. Slope steepness and tolerance for erosion both show greater potential for erosion in B9 than in B8 and in B8 than in B7. An examination of the soil mapping units involved indicates that some soils in B8 are prone to soil erosion, and nearly all soil mapping units in B9 have potentially excessive erosion.

Our study indicated a large potential for soil erosion control with moderately improved tillage and surface residue management; however, it was also obvious that the *C* values must be more accurately assessed. Tillage and residue managements in table 5 are typical of the study area; they also represent the more advanced forms of reduced tillage and surface residue maintenance. There are, however, many more tillage and residue management options than those shown in table 5. Table 25 shows options of spring plowing in a WF system along with *C* values. Table 5 allowed moldboard plowing (in the spring of a fallow year) only when the surface residue after wheat planting was to be 110 kg/ha, whereas table 25 shows that spring plowing inflates the *C* value in the WF sequence, especially where there is to be more than 110 kg/ha of residue on the surface after wheat planting. The footnotes in table 25 also indicate that the true *C* value must be larger than that shown for the 840 and 1,960 kg/ha of surface residue. Fall moldboard plowing is often used instead of spring moldboard plowing; in these cases, one can expect at least a 30 percent increase of *C* value. Consideration should be given to *C* values for reduced primary tillages (chisel or sweep) in the fall after wheat harvest. A large amount of surface residue (1,960 kg/ha in X_4) was required to maintain erosion control, especially on the steeper slopes. This cover management requires about 4,000 kg/ha of residue at harvest, the required management consists of drastically reduced and no-till procedures for which present technology is not adequate (Papendick and Miller, *1977*).

A similar technology inadequacy restricts the use of X_6 in the WP sequence because the standing stubble (with no fall moldboard tillage after wheat) produces excessively wet soil conditions in spring, delays pea planting, and suppresses pea growth, especially in B9. Here is a case where some form of residue harvest and planting, without the usual preplant tillage, would be a technological improvement.

Table 25.--*Dependence of* C *value on the frequency of moldboard plowing in the spring of the fallow year in a wheat-fallow sequence in Major Land Resource Areas B7, B8, and B9*

Surface residue after wheat planting (kg/ha)	*C* value for the indicated frequency of moldboard plowing in spring of fallow year			
	No moldboard plowing	Every other fallow year	Every third fallow year	Every fourth fallow year
110[1]	0.35	0.35	0.35	0.35
390	.29	.32	.31	.30
840	.19	[2].27	[2].24	.23
1960	.10	[2].22	[2].18	.16

[1]Moldboard plowing in spring of every summerfallow year.
[2]Specified surface residue attainable after wheat planting only in years when moldboard plowing not performed.

While there may be some errors in estimating *C* values, tillage and surface residue maintenance dominated as an erosion control practice. This evidence pinpoints a critical need for machinery systems to perform tillage and planting operations and yet maintain surface residue. Undoubtedly, cereal varieties are also needed to tolerate heavy surface residues (Oschwald, *1978*). Since there is so little ground truth for evaluating soil erosion in the Pacific Northwest, additional research must answer the question, "will surface residues and associated tillage actually control erosion as well as projected in this study?"

Slope length reduction and contouring proved to be most effective for soil erosion control when used along with good tillage and surface residue management. Contouring was projected to be effective even on slopes below 10 percent. Terracing as related to slope length was also projected to be effective, but cost considerations would favor its use when less costly control measures (contouring, tillage, and residue management) cannot provide erosion control. The average unbroken slope length of 219 m in table 9, as determined by the absence of large slope changes or sediment deposition, characterizes long steep slopes upon which contouring and terracing can be effective. This effectiveness of terracing accounts for the significant increase of terracing in the study area (Mouchett, *1978*). Projected effectiveness and widespread use of contouring operations warrant a more careful evaluation of the *P* values as related to drill types, tracks provided by wheeled and crawler-type tractors, and length of uninterrupted slope. We did not apply the *P* practice in strict accordance with the associated slope lengths specified by Wischmeier and Smith (*1978*).

Year-to-year variations in soil erosion and crop residue production were not addressed because application of the USLE projects average annual soil losses in response to average rainfall and erosion energy as well as average cover management factors. Residue production varied (year to year) from about 25 to 50 percent depending on the crop (table 10). Tillage for control of surface residue also varied from year to year. This variation, combined with the scattered characteristics of the fields from which residue can be harvested for bioenergy, detracts from profitable use of residues for servicing bioenergy needs discussed by Larson et al. (*1978*).

Any decision to harvest residues in the study area must be made after considering several other benefits of surface residue in addition to those for water erosion control. B7 has a serious wind erosion control problem; consesequently, residue harvests from the flatter slopes (in accord with low projected soil erosion from water) would aggravate wind erosion. Crop residues, either standing or matted on the surface, enhance water conservation during the mild wet winters; an overall increase of 150 kg of grain/ha is a conservative estimate of the benefit.

Further understandings of soil erosion in the study area could be made by estimating management effects on soil erosion from the adjacent nontilled cropland, which may be a potential source of sediment pollution because of its proximity to streams. Soil erosion from the forest and rangelands was also not accounted for in our analysis.

The natural correlation between hydrologic group and erosion tolerance values suggests that the runoff effects on soil erosion ought to be assessed based on an extension of the preliminary work of Onstad and Otterby (*1979*).

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APPENDIX TABLES

Appendix table 1.--*Listing of soil characteristics, fixed parameters of the Universal Soil Loss Equation (USLE), and crop sequence for the tilled cropland, and nontilled adjacent cropland in Major Land Resource Area B7 in 6 northeastern Oregon counties*

County and soil type[1]	Slope phase	Hydrologic group	Parameters of USLE: T[2]	R_T	K	S	Fraction tilled[3]	Tilled cropland: Area	Crop sequence[4]	Nontilled adjacent cropland area
	Percent		*Tonnes/ ha*		*Tonnes/ ha per year*	*Percent*		*Hectares*		*Hectares*
Gilliam										
Ritzville si l, co mdp	7-20	B	11.2	20.8	0.63	13.5	0.75	3642	WF	1214
Sandy alluvial land	0-1	A	11.2	17.4	.13	.5	.08	99	WF	1208
Morrow										
Quincy l s[5]	0-3	A	11.2	17.4	.13	1.5	.75	4534	WF	1512
Quincy l s[5]	3-7	A	11.2	17.4	.13	5.0	.75	2250	WF	750
Quincy f s[5]	3-7	A	11.2	17.4	.13	5.0	.75	9830	WF	3279
Sagehill f s l[5]	3-7	B	11.2	20.8	.41	5.0	.50	2933	WF	2221
Sagehill f s l[5]	7-12	B	11.2	20.8	.41	9.5	.50	1511	WF	1144
Sagemoor f s l[5]	0-3	C	6.7	20.8	.63	1.5	.50	4489	WF	4223
Sagemoor f s l[5]	7-12	C	6.7	20.8	.63	9.5	.50	1322	WF	1243
Umatilla										
Ellisforde si l	0-3	C	11.2	20.8	.56	1.5	.95	2143	WF	113
Ellisforde si l	3-7	C	11.2	20.8	.56	5.0	.95	1408	WF	74
Esquatzel si l	0-3	B	11.2	20.8	.56	1.5	.90	709	WF	79
Hermiston si l	0-3	B	11.2	20.8	.48	1.5	.90	894	WF	100
Onyx si l	0-3	B	11.2	20.8	.56	1.5	.95	567	WF	30
Pedigo si l	0-3	B/C	11.2	20.8	.56	1.5	.95	635	WF	34
Quincy l s	0-3	A	11.2	17.4	.13	1.5	.75	11136	WF	3712
Quincy l s	3-7	A	11.2	17.4	.13	4.6	.75	4413	WF	1471
Quincy l s	7-12	A	11.2	17.4	.13	9.0	.75	1247	WF	416
Quincy l s	12-20	A	11.2	17.4	.13	15.2	.75	1386	WF	462
Quincy l s, wet	0-3	A	11.2	17.4	.13	1.2	.75	578	WF	193
Ritzville si l	0-3	B	11.2	20.8	.63	1.5	.95	4999	WF	263
Ritzville si l	3-7	B	11.2	20.8	.63	5.0	.95	2972	WF	157
Ritzville si l	7-12	B	11.2	20.8	.63	9.5	.95	3760	WF	198
Ritzville si l	12-20	B	11.2	20.8	.63	16.0	.95	4111	WF	216
Ritzville si l	20-35	B	11.2	20.8	.63	27.5	.20	261	WF	1044
Sagehill f s l	3-7	B	11.2	20.8	.41	5.0	.50	2294	WF	2295
Sagehill f s l	7-12	B	11.2	20.8	.41	9.0	.50	988	WF	988
Sagemoor si l	3-7	C	6.7	20.8	.63	5.0	.50	714	WF	714
Stanfield si l	0-3	C	2.2	20.8	.56	1.5	.90	284	WF	32
Umapine si l	0-3	B/C	11.2	20.8	.63	1.5	.90	787	WF	87
Yakima l	0-3	B	4.5	20.8	.63	1.5	.50	199	WF	199

[1]Abbreviations as defined in Soil Survey Manual (Soil Survey Staff, *1951*).

[2]Source: Soil Conservation Service. Soils Interpretations for Oregon (OR-Soils-1). Continuous reissue. Portland, Oreg.

[3]Recorded tilled cropland area divided by this number will give total area.

[4]WF = Wheat-fallow (2-yr sequence).

[5]These areas reduced 50 percent to account for land in military reservation.

Appendix table 2.--*Listing of soil characteristics, fixed parameters of the Universal Soil Loss Equation (USLE), and crop sequence for the tilled cropland, and nontilled adjacent cropland in Major Land Resource Area B8 in 6 northeastern Oregon counties*

County and soil type[1]	Slope phase	Hydrologic group	Parameters of USLE: T[2]	R_T	K	S	Fraction tilled[3]	Tilled cropland: Area	Crop sequence[4]	Nontilled adjacent cropland area
	Percent		*Tonnes/ ha*		*Tonnes/ ha per year*	*Per- cent*		*Hectares*		*Hectares*
Gilliam										
Condon si l	3-7	C	4.5	30.4	0.56	4.6	0.85	21504	WF	3795
Condon si l	7-12	C	4.5	30.4	.56	9.0	.80	5770	WF	1442
Condon si l	12-20	C	4.5	30.4	.56	15.2	.73	804	WF	297
Condon si l	30-45	C	4.5	30.4	.56	36.0	.50	39	WF	37
Condon si l, dp ph	1-7	C	11.2	30.4	.56	4.6	.85	2885	WF	509
Condon si l, dp ph N	7-12	C	11.2	30.4	.56	9.0	.80	1485	WF	371
Condon si l, dp ph	12-20	C	11.2	30.4	.56	15.2	.73	207	WF	76
Condon si l, N	7-12	C	11.2	30.4	.56	9.0	.80	2571	WF	643
Condon si l, N	12-20	C	11.2	30.4	.56	15.2	.73	358	WF	132
Condon si l, sh var	7-12	C	4.5	30.4	.56	9.0	.35	850	WF	1578
Condon si l, sh var	12-20	C	4.5	30.4	.56	15.2	.73	270	WF	101
Condon si l, dp ph N	30-45	C	11.2	30.4	.56	36.0	.50	44	WF	44
Hermiston si l	0-3	B	11.2	29.7	.48	1.2	.90	583	WF	65
Morrow si l	3-7	C	4.5	32.8	.48	4.6	.73	5165	WF	1910
Morrow si l	7-12	C	4.5	32.8	.48	9.0	.73	4390	WF	1624
Morrow si l	30-45	C	4.5	32.8	.48	36.0	.50	1862	WF	1862
Onyx si l, dp ph	0-3	B	11.2	29.2	.45	1.2	.97	1217	WF	38
Quincy sa	3-7	A	11.2	26.0	.13	4.6	.10	53	WF	473
Quincy l sa	0-3	A	11.2	26.0	.13	1.2	.75	486	WF	162
Quincy l sa	3-7	A	11.2	26.0	.13	4.6	.75	91	WF	30
Quincy l sa	7-12	A	11.2	26.0	.13	9.0	.75	759	WF	253
Quincy l sa	12-20	A	11.2	26.0	.13	15.2	.75	364	WF	121
Quincy l sa	20-35	A	11.2	26.0	.13	26.0	.50	526	WF	526
Ritzville si l	0-3	B	6.7	27.9	.63	1.2	.91	5561	WF	550
Ritzville si l	3-7	B	11.2	27.9	.63	4.6	.91	2936	WF	290
Ritzville si l, co dp ph	3-7	B	11.2	27.9	.63	4.6	.91	13377	WF	1323
Ritzville si l, co dp ph S	7-12	B	6.7	27.9	.63	9.0	.75	8586	WF	2862
Ritzville si l, co dp ph S	12-20	B	6.7	27.9	.63	15.2	.50	225	WF	225
Ritzville si l, mdp S	7-12	B	6.7	27.9	.63	9.0	.75	795	WF	265
Ritzville si l, mdp S	12-20	B	6.7	27.9	.63	15.2	.50	23	WF	23
Ritzville si l, dp ph N	7-12	B	11.2	27.9	.63	9.0	.75	636	WF	212
Ritzville si l, dp N	12-20	B	11.2	27.9	.63	15.2	.73	25	WF	9
Ritzville si l, co dp N	20-35	B	11.2	27.9	.63	26.0	.10	37	WF	336
Ritzville si l, mdp S	20-35	B	11.2	27.9	.63	26.0	.10	56	WF	504
Sagemoor si l	0-3	C	6.7	26.0	.63	1.2	.50	789	WF	789
Sagemoor si l	7-12	C	6.7	26.0	.63	9.0	.50	121	WF	121
Sagemoor si l	12-20	C	6.7	26.0	.63	15.2	.50	1801	WF	1801
Walla Walla si l	0-3	B	6.7	31.1	.63	1.2	.95	769	WF	40
Walla Walla si l	3-7	B	6.7	31.1	.63	4.6	.95	15570	WF	819
Walla Walla si l	7-12	B	6.7	31.1	.63	9.0	.85	11902	WF	2100
Walla Walla si l co solm	3-7	B	9.0	31.1	.63	4.6	.95	577	WF	30
Walla Walla si l, co solm	7-12	B	9.0	31.1	.63	9.0	.95	1384	WF	73
Morrow										
Condon si l	2-7	C	4.5	31.1	.56	4.0	.85	7750	WF	1368
Condon si l, dp	7-20	C	11.2	31.1	.56	12.2	.73	665	WF	246
Condon si l, N	12-20	C	11.2	31.1	.56	15.2	.73	2441	WF	903
Condon si l, sh var	12-20	C	4.5	31.1	.56	15.2	.40	5374	WF	8389
Hermiston f s l, dp	0-5	B	11.2	31.1	.48	2.0	.85	641	WF	113
Hermiston si l	0-5	B	11.2	31.1	.48	2.0	.85	769	WF	136
Morrow si l, mdp	2-5	C	4.5	31.1	.48	3.2	.85	1077	WF	190
Morrow si l, mdp N	12-20	C	4.5	31.1	.48	15.2	.73	660	WF	244
Morrow si l, mdp S	12-20	C	4.5	31.1	.48	15.2	.73	3965	WF	1466
Morrow si l, N	20-35	C	4.5	31.1	.48	26.0	.50	5069	WF	5069
Morrow si l, sh var	5-12	C	4.5	31.1	.48	7.8	.30	760	WF	1774

Appendix table 2.--*Listing of soil characteristics, fixed parameters of the Universal Soil Loss Equation (USLE), and crop sequence for the tilled cropland, and nontilled adjacent cropland in Major Land Resource Area B8 in 6 northeastern Oregon counties*--Continued

County and soil type[1]	Slope phase	Hydrologic group	Parameters of USLE: T^2	R_T	K	S	Fraction tilled[3]	Tilled cropland: Area	Crop sequence[4]	Nontilled adjacent cropland area
	Percent		*Tonnes/ ha*		*Tonnes/ ha per year*	*Per-cent*		*Hec-tares*		*Hec-tares*
Morrow										
Onyx si l, dp	0-3	B	11.2	29.2	0.45	1.2	0.95	2068	WF	109
Onyx si l, mdp	0-3	B	11.2	29.2	.45	1.2	.95	1316	WF	69
Ritzville co si l	2-7	B	11.2	27.9	.63	4.0	.95	14119	WF	743
Ritzville si l	2-7	B	11.2	27.9	.63	4.0	.95	19185	WF	959
Ritzville si l, mdp	2-7	B	11.2	27.9	.63	4.0	.95	5134	WF	270
Ritzville si l, mdp S	2-7	B	11.2	27.9	.63	4.0	.90	4377	WF	486
Ritzville si l, N	7-20	B	11.2	27.9	.63	12.2	.90	8998	WF	1000
Ritzville si l, N	12-20	B	11.2	27.9	.63	15.2	.90	486	WF	54
Ritzville si l, S	12-20	B	11.2	27.9	.63	15.2	.90	4864	WF	540
Ritzville si l, S	20-40	B	11.2	27.9	.63	28.0	.35	2776	WF	5156
Valby si l	1-7	C	4.5	29.2	.63	3.4	.85	16477	WF	2908
Valby si l	7-12	C	4.5	29.2	.63	9.0	.85	6742	WF	1190
Valby si l	12-20	C	4.5	29.2	.63	15.2	.85	2717	WF	480
Valby si l	20-30	C	4.5	29.2	.63	24.0	.75	425	WF	142
Walla Walla si l	1-7	B	6.7	30.4	.63	3.4	.95	7112	WF	374
Walla Walla si l	7-12	B	6.7	30.4	.63	9.0	.95	5152	WF	271
Walla Walla si l	12-20	B	6.7	30.4	.63	15.2	.90	838	WF	93
Walla Walla si l, N	12-20	B	11.2	30.4	.63	15.2	.90	838	WF	93
Yakima gr f s l, mdp	0-3	B	4.5	29.7	.26	1.2	.50	456	WF	456
Sherman										
Clayey basin land	0-3	C	4.5	30.4	.56	1.0	1.00	70	WF	--
Condon si l, N	2-7	C	4.5	29.7	.56	4.0	.87	29177	WF	4360
Condon si l, N	7-12	C	4.5	29.7	.56	9.0	.73	2665	WF	986
Condon si l, N	12-20	C	4.5	29.7	.56	15.2	.45	1821	WF	2226
Condon si l, N	20-35	C	4.5	29.7	.56	26.0	.10	107	WF	963
Condon si l, dp	1-7	B	11.2	29.7	.56	3.4	.98	6339	WF	128
Condon si l, dp N	7-20	B	11.2	29.7	.56	12.2	.90	1119	WF	123
Condon si l, sh var	7-12	C	4.5	29.7	.56	9.0	.36	297	WF	561
Condon si l, sh var N	20-35	C	4.5	29.7	.56	26.0	.01	2	WF	233
Hermiston l	0-3	B	11.2	31.1	.48	1.2	.15	101	WF	574
Kuhl v ro v f s l	3-7	D	2.2	28.4	.37	4.6	.01	4	WF	357
Pedigo si l	0-3	B/C	11.2	31.1	.51	1.2	.10	9	WF	64
Ritzville si l	2-7	B	11.2	27.9	.63	4.0	.91	1798	WF	178
Ritzville si l, N	7-20	B	11.2	27.9	.63	15.0	.85	664	WF	117
Ritzville si l, mdp	2-5	B	11.2	27.9	.63	3.2	.70	1013	WF	435
Ritzville si l, mdp N	7-20	B	11.2	27.9	.63	12.2	.68	433	WF	202
Ritzville si l, mdp N	20-35	B	11.2	27.9	.63	26.0	.01	3	WF	257
Ritzville si l, mdp S	7-20	B	11.2	27.9	.63	12.2	.74	763	WF	267
Sagemoor si l	7-20	C	6.7	26.0	.63	12.2	.01	13	WF	1543
Sandy alluvial land	0-3	A	11.2	26.0	.32	1.2	.08	119	WF	1417
Walla Walla si l, vdp	3-7	B	11.2	31.1	.63	4.6	.99	11493	WF	117
Walla Walla si l, vdp N	7-20	B	11.2	31.1	.63	12.2	.97	5702	WF	176
Walla Walla si l, vdp N	20-35	B	11.2	31.1	.63	26.0	.74	331	WF	117
Walla Walla si l, vdp S	7-20	B	11.2	31.1	.63	12.2	.98	1337	WF	27
Walla Walla si l, dp	1-7	B	6.7	31.1	.63	3.4	.95	1073	WF	56
Walla Walla si l, dp N	7-20	B	6.7	31.1	63	12.2	.88	433	WF	59
Walla Walla si l, dp S	7-20	B	6.7	31.1	.63	12.2	.96	1454	WF	60
Walla Walla si l, mdp	1-7	B	6.7	31.1	.63	3.4	.85	868	WF	153
Walla Walla si l, mdp N	7-20	B	6.7	31.1	.63	12.2	.87	199	WF	30
Walla Walla si l, mdp N	20-35	B	6.7	31.1	.63	26.0	.14	42	WF	248
Walla Walla si l, mdp S	7-20	B	6.7	31.1	.63	12.2	.87	1729	WF	258
Walla Walla si l, cslm vdp	3-7	B	11.2	31.1	.63	4.6	.98	5702	WF	116
Walla Walla si l, cslm vdp N	7-20	B	11.2	31.1	.63	12.2	.97	2450	WF	76
Walla Walla si l, cslm vdp N	20-35	B	11.2	31.1	.63	26.0	.77	697	WF	208

Appendix table 2.--*Listing of soil characteristics, fixed parameters of the Universal Soil Loss Equation (USLE), and crop sequence for the tilled cropland, and nontilled adjacent cropland in Major Land Resource Area B8 in 6 northeastern Oregon counties*--Continued

County and soil type[1]	Slope phase	Hydrologic group	Parameters of USLE: T^2	R_T	K	S	Fraction tilled[3]	Tilled cropland: Area	Crop sequence[4]	Nontilled adjacent cropland area
	Percent		*Tonnes/ha*		*Tonnes/ha per year*	*Percent*		*Hectares*		*Hectares*
Sherman										
Walla Walla si l, cslm vdp S	7-20	B	11.2	31.1	0.63	12.2	0.98	1382	WF	28
Walla Walla si l, cslm vdp S	20-35	B	11.2	31.1	.63	26.0	.89	403	WF	50
Walla Walla si l, cslm dp	3-7	B	6.7	31.1	.63	4.6	.95	2106	WF	110
Walla Walla si l, cslm dp N	7-20	B	6.7	31.1	.63	12.2	.93	425	WF	32
Walla Walla si l, cslm dp N	20-35	B	6.7	31.1	.63	26.0	.20	68	WF	264
Walla Walla si l, cslm dp S	7-20	B	6.7	31.1	.63	12.2	.98	1175	WF	24
Walla Walla si l, cslm dp S	20-35	B	6.7	31.1	.63	26.0	.77	174	WF	52
Walla Walla si l, cslm mdp	3-7	B	6.7	31.1	.63	4.6	.91	1631	WF	161
Walla Walla si l, cslm mdp N	7-20	B	6.7	31.1	.63	12.2	.28	77	WF	196
Walla Walla si l, cslm mdp S	7-20	B	6.7	31.1	.63	12.2	.87	463	WF	69
Walla Walla si l, cslm mdp S	20-35	B	6.7	31.1	.63	26.0	.73	166	WF	61
Walla Walla si l, lrfl vdp	3-7	B	11.2	29.3	.63	4.6	.98	6029	WF	123
Walla Walla si l, lrfl vdp N	7-20	B	11.2	29.3	.63	12.2	.97	1891	WF	58
Walla Walla si l, lrfl vdp N	20-35	B	11.2	29.3	.63	26.0	.51	170	WF	164
Walla Walla si l, lrfl dp	3-7	B	9.0	29.3	.63	4.6	.98	4665	WF	96
Walla Walla si l, lrfl dp N	7-20	B	9.0	29.3	.63	12.2	.95	1645	WF	87
Walla Walla si l, lrfl dp S	7-20	B	9.0	29.3	.63	12.2	.98	427	WF	9
Walla Walla si l, lrfl mdp	3-7	B	6.7	29.3	.63	4.6	.85	3963	WF	697
Walla Walla si l, lrfl mdp N	7-20	B	6.7	29.3	.63	12.2	.84	534	WF	101
Walla Walla si l, lrfl mdp N	20-35	B	6.7	29.3	.63	26.0	.22	49	WF	170
Walla Walla si l, lrfl mdp S	7-20	B	6.7	29.3	.63	12.2	.78	2500	WF	703
Walla Walla v f s l, dp	3-7	B	9.0	29.3	.48	4.6	.80	1091	WF	272
Walla Walla v f s l, dp N	7-20	B	9.0	29.3	.48	12.2	.80	1197	WF	300
Walla Walla v f s l, dp N	20-35	B	9.0	29.3	.48	26.0	.43	273	WF	363
Walla Walla v f s l, dp S	7-20	B	9.0	29.3	.48	12.2	.84	1029	WF	196
Walla Walla v f s l, dp S	20-35	B	9.0	29.3	.48	26.0	.59	207	WF	144
Walla Walla v f s l, mdp	3-7	B	9.0	29.3	.48	4.6	.77	324	WF	96
Walla Walla v f s l, mdp S	7-20	B	9.0	29.3	.48	12.2	.74	204	WF	71
Walla Walla v f s l, mdp S	20-35	B	9.0	29.3	.48	26.0	.30	28	WF	66
Walvan l	2-10	B	11.2	31.1	.63	5.2	.85	392	WF	69
Umatilla										
Condon si l	2-7	C	4.5	29.7	.56	4.0	.85	4726	WF	834
Condon si l	7-12	C	4.5	29.7	.56	9.0	.85	3290	WF	580
Condon si l, dp	7-20	B	11.2	29.7	.56	12.2	.85	1496	WF	264
Condon si l, dp N	7-20	B	11.2	29.7	.56	12.2	.85	1496	WF	264
Condon si l, N	7-12	C	4.5	29.7	.56	9.0	.85	2692	WF	475
Condon si l, S	12-20	C	4.5	29.7	.56	15.2	.50	352	WF	352
Condon si l, sh var	12-20	C	4.5	29.7	.56	15.2	.50	1056	WF	1055
Condon si l, sh var N	7-12	C	4.5	29.7	.56	9.0	.50	176	WF	176
Hermiston f s l, dp	0-3	B	11.2	31.1	.45	1.2	.90	1457	WF	162
Morrow si l	3-7	C	4.5	32.3	.48	4.6	.85	6454	WF	1139
Morrow si l	7-12	C	4.5	32.3	.48	9.0	.85	3040	WF	537
Morrow si l	12-20	C	4.5	32.3	.48	15.2	.50	263	WF	263
Morrow si l	20-35	C	4.5	32.3	.48	26.0	.20	65	WF	259
Pilot Rock si l	1-3	C	2.2	32.3	.63	1.2	.90	2433	WF	270
Pilot Rock si l	3-7	C	2.2	32.3	.63	4.6	.90	5864	WF	652
Pilot Rock si l	7-12	C	2.2	32.3	.63	9.0	.90	6556	WF	728
Pilot Rock si l	12-20	C	2.2	32.3	.63	15.2	.90	1427	WF	159
Ritzville si l	2-7	B	11.2	27.9	.63	4.0	.95	4680	WF	246
Ritzville si l	20-40	B	11.2	27.9	.63	28.0	.10	105	WF	950
Ritzville si l, dp	2-5	B	11.2	27.9	.63	3.2	.95	12702	WF	669
Ritzville si l, dp	12-20	B	11.2	27.9	.63	15.2	.85	4230	WF	747
Ritzville si l, mdp	7-12	B	11.2	27.9	.63	9.0	.95	14374	WF	756
Ritzville si l, N	20-40	B	11.2	27.9	.63	28.0	.20	70	WF	282

Appendix table 2.--*Listing of soil characteristics, fixed parameters of the Universal Soil Loss Equation (USLE), and crop sequence for the tilled cropland, and nontilled adjacent cropland in Major Land Resource Area B8 in 6 northeastern Oregon counties*--Continued

County and soil type[1]	Slope phase	Hydrologic group	Parameters of USLE: T[2]	R_T	K	S	Fraction tilled[3]	Tilled cropland: Area	Crop sequence[4]	Nontilled adjacent cropland area
	Percent		*Tonnes/ha*		*Tonnes/ha per year*	*Percent*		*Hectares*		*Hectares*
Umatilla										
Sagemoor si l	3-7	C	6.7	26.0	0.63	6.6	0.65	1504	WF	810
Waha si l	7-12	C	6.7	34.7	.41	9.0	.80	304	WF	76
Walla Walla si l	0-3	B	9.0	31.1	.63	1.2	.97	5435	WF	168
Walla Walla si l	3-7	B	9.0	31.1	.63	4.6	.97	11336	WF	350
Walla Walla si l	7-12	B	9.0	31.1	.63	9.0	.97	8364	WF	259
Walla Walla si l	12-20	B	9.0	31.1	.63	15.2	.97	405	WF	13
Walla Walla si l, cslm	0-3	B	9.0	28.4	.63	1.2	.97	2194	WF	68
Walla Walla si l, cslm	3-7	B	9.0	28.4	.63	4.6	.97	6167	WF	191
Walla Walla si l, cslm	7-12	B	9.0	28.4	.63	9.0	.97	5378	WF	166
Walla Walla si l, cslm	12-20	B	9.0	28.4	.63	15.2	.97	4638	WF	143
Walla Walla si l, cslm	20-35	B	9.0	28.4	.63	26.0	.50	956	WF	956
Walla Walla si l, N	7-12	B	9.0	31.1	.63	9.0	.97	744	WF	23
Walla Walla si l, N	12-20	B	9.0	31.1	.63	15.2	.97	364	WF	11
Walla Walla si l, vdp	0-3	B	11.2	31.1	.63	1.2	.97	3225	WF	100
Walla Walla si l, vdp	3-7	B	11.2	31.1	.63	4.6	.97	6725	WF	208
Walla Walla si l, vdp	7-12	B	11.2	31.1	.63	9.0	.97	1115	WF	34
Walla Walla si l, vdp	12-20	B	11.2	31.1	.63	15.2	.97	121	WF	4
Walla Walla si l, h rnfl	0-3	B	11.2	33.5	.63	1.2	.97	2282	WF	110
Walla Walla si l, h rnfl	3-7	B	11.2	33.5	.63	4.6	.97	6392	WF	309
Walla Walla si l, h rnfl	7-12	B	11.2	33.5	.63	9.0	.97	10763	WF	520
Walla Walla si l, h rnfl	12-20	B	11.2	33.5	.63	15.2	.97	4160	WF	201
Walvan l	20-35	B	11.2	31.1	.63	26.0	.50	860	WF	860
Walla Walla si l, h rnfl	0-3	B	11.2	33.5	.63	1.2	.97	1284	WP	--
Walla Walla si l, h rnfl	3-7	B	11.2	33.5	.63	4.6	.97	3579	WP	--
Walla Walla si l, h rnfl	7-12	B	11.2	33.5	.63	9.0	.97	6054	WP	--
Walla Walla si l, h rnfl	12-20	B	11.2	33.5	.63	15.2	.97	2340	WP	--
Wasco										
Cantala si l	1-7	B	9.0	29.3	.56	3.4	.85	19263	WF	3399
Cantala si l	7-12	B	9.0	29.3	.56	9.0	.85	7224	WF	1275
Cantala si l	12-20	B	9.0	29.3	.56	15.2	.35	2974	WF	5524
Cantala si l	20-35	B	9.0	29.3	.56	26.0	.35	991	WF	1841
Condon si l	2-7	C	4.5	29.3	.56	4.0	.85	11661	WF	2058
Condon si l	7-20	C	4.5	29.3	.56	12.0	.85	1066	WF	188
Dufur si l	1-7	B	6.7	29.3	.56	3.4	.85	3079	WF	543
Dufur si l	25-40	B	6.7	29.3	.56	31.0	.35	571	WF	1059
Dufur si l, mdp	1-7	B	11.2	29.3	.56	3.4	.85	154	WF	27
Dufur si l, mdp	25-40	B	11.2	29.3	.56	31.0	.35	127	WF	235
Dufur si l, mdp S	12-25	B	11.2	29.3	.56	17.2	.50	362	WF	362
Dufur si l, S	12-25	B	6.7	29.3	.56	17.2	.85	2463	WF	435
Dufur si l, S	25-40	B	6.7	29.3	.56	31.0	.35	1648	WF	3061
Maupin l	0-5	C	4.5	28.4	.48	2.0	.85	5091	WF	898
Maupin l	5-12	C	4.5	28.4	.48	7.8	.50	668	WF	668
Maupin l, dp var	0-5	C	4.5	28.4	.48	2.0	.85	585	WF	103
Onyx si l	0-3	B	11.2	29.7	.51	1.2	1.00	724	WF	--
Sandy alluvial land	0-7	A	11.2	30.4	.32	2.8	.10	417	WF	3749
Sinamox si l	12-20	B	6.7	29.3	.63	15.2	.85	1231	WF	217
Tygh f s l	0-3	B	6.7	34.7	.26	1.2	.85	616	WF	108
Walla Walla si l	3-7	B	6.7	31.1	.63	4.6	.95	6305	WF	332
Walla Walla si l	7-12	B	6.7	31.1	.63	9.0	.95	5805	WF	305
Walla Walla si l, N	12-20	B	11.2	31.1	.63	15.2	.73	3338	WF	1235
Walla Walla si l, N	20-35	B	11.2	31.1	.63	26.0	.50	1275	WF	1275
Walla Walla si l, S	12-20	B	6.7	31.1	.63	15.2	.73	1123	WF	415
Wamic l	1-5	B	11.2	34.7	.63	2.6	.65	3768	WF	2029
Wamic l	5-12	B	11.2	34.7	.63	7.8	.65	236	WF	127

Appendix table 3.--*Listing of soil characteristics, fixed parameters of the Universal Soil Loss Equation (USLE), and crop sequence for the tilled cropland, and nontilled adjacent cropland in Major Land Resource Area B8 in 6 northeastern Oregon counties*--Continued

County and soil type[1]	Slope phase	Hydrologic group	Parameters of USLE: T[2]	R_T	K	S	Fraction tilled[3]	Tilled cropland: Area	Crop sequence[4]	Nontilled adjacent cropland area
	Percent		*Tonnes/ ha*		*Tonnes/ ha per year*	*Per- cent*		*Hec- tares*		*Hec- tares*
Umatilla										
Tolo si l	35-60	B	11.2	46.8	0.71	45.0	0.10	214	WF	1931
Waha si l	0-3	C	4.5	38.0	.29	1.2	.80	199	WF	78
Waha si l	3-7	C	4.5	38.0	.29	4.6	.80	725	WF	283
Waha si l	7-12	C	4.5	38.0	.29	9.0	.80	6087	WF	2378
Waha si l	12-20	C	4.5	38.0	.29	15.2	.80	3401	WF	1329
Waha si l	20-35	C	4.5	38.0	.29	26.0	.50	4074	WF	6366
Waha si l	35-60	C	4.5	38.0	.29	45.0	.10	833	WF	7500
Walla Walla si l, h rnfl	7-12	B	11.2	34.7	.63	9.0	.95	565	WF	47
Athena si l	0-3	B	11.2	39.0	.56	1.2	.95	2152	WP	--
Athena si l	3-7	B	11.2	39.0	.56	4.6	.95	4473	WP	--
Athena si l	7-12	B	11.2	39.0	.56	9.0	.95	830	WP	--
Couse si l	3-7	C	2.2	46.8	.43	4.6	.15	130	WP	--
McKay si l	3-7	D	6.7	32.8	.48	4.6	.97	1879	WP	--
Palouse si l	0-3	B	11.2	43.4	.41	1.2	.95	310	WP	--
Palouse si l	7-12	B	11.2	43.4	.41	9.0	.95	1087	WP	--
Palouse si l	12-20	B	11.2	43.4	.41	15.2	.95	1263	WP	--
Palouse si l	20-35	B	11.2	43.4	.41	26.0	.50	100	WP	--
Waha si l	0-3	C	4.5	38.0	.41	1.2	.80	112	WP	--
Waha si l	3-7	C	4.5	38.0	.41	4.6	.80	407	WP	--
Waha si l	7-12	C	4.5	38.0	.41	9.0	.80	3424	WP	--
Waha si l	12-20	C	4.5	38.0	.41	15.2	.80	957	WP	--
Waha si l	20-35	C	4.5	38.0	.41	26.0	.50	1146	WP	--
Walla Walla si l, h rnfl	7-12	B	11.2	34.7	.63	9.0	.95	317	WP	--
Wallowa										
Chesnimus si l	0-3	B	6.7	34.7	.31	1.5	.90	4715	H4G2	524
Couse si l	3-7	C	2.2	34.7	.43	5.0	.30	6107	WF	14250
Couse si l	7-12	C	2.2	34.7	.43	9.5	.30	1434	WF	3346
Hurwal si l	15-30	B	11.2	34.7	.31	22.5	.30	917	WF	2140
Hurwal si l	30-50	B	11.2	34.7	.31	40.0	.20	1528	WF	6113
Hurwal si l, thn solum	30-50	B	6.7	34.7	.31	40.0	.10	44	WF	393
Lostine si l	3-7	B	2.2	34.7	.41	5.0	.80	1048	H4G2	262
Powwatka si l	1-8	C	2.2	34.7	.32	4.5	.25	983	WF	2947
Powwatka si l, o/gr	15-30	C	2.2	34.7	.32	22.5	.25	327	WF	983
Powwatka si l, o/st	1-15	C	2.2	34.7	.32	8.0	.25	1583	WF	4749
Redmount sa l	1-3	B	2.2	34.7	.26	2.0	.75	2129	H4G2	709
Redmount sa l	3-7	B	2.2	34.7	.26	5.0	.75	2620	H4G2	873
Redmount si l	1-3	B	2.2	34.7	.41	2.0	.75	2947	H4G2	983
Redmount si l	3-7	B	2.2	34.7	.41	5.0	.75	163	H4G2	55
Randowa si l	3-7	B	4.5	34.7	.41	5.0	.20	131	WF	524
Snow si l	0-2	B	11.2	34.7	.48	1.0	.75	1473	H4G2	491
Tolo si l	1-12	B	11.2	34.7	.71	6.5	.25	84	WF	253
Tolo si l, m well dr	1-12	B	11.2	34.7	.71	6.5	.25	2197	WF	6593
Tolo si l, mdp o/sa	1-12	B	11.2	34.7	.71	6.5	.25	1521	WF	4564
Zumwalt si l	1-8	C	2.2	34.7	.41	4.5	.50	2401	WF	2401
Zumwalt si l, lt color	1-8	C	2.2	34.7	.41	4.5	.50	2401	WF	2401
Wallowa-Anatone cmplx	1-15	C	4.5	34.7	.32	8.0	.10	1681	WF	15129

[1]Abbreviations as defined in Soil Survey Manual (Soil Survey Staff, *1951*).

[2]Source: Soil Conservation Service. Soils Interpretations for Oregon (OR-Soils-1). Continuous Reissue. Portland, Oreg.

[3]Recorded tilled cropland area divided by this number will give total area.

[4]WF = Wheat-fallow (2-yr sequence); H4G2 = hay 4 yr, small grain 2 yr (6-yr sequence).

Note: Dashes indicate no adjacent nontilled cropland.

Appendix table 2.--*Listing of soil characteristics, fixed parameters of the Universal Soil Loss Equation (USLE), and crop sequence for the tilled cropland, and nontilled adjacent cropland in Major Land Resource Area B8 in 6 northeastern Oregon counties*--Continued

County and soil type[1]	Slope phase	Hydrologic group	Parameters of USLE: T^2	R_T	K	S	Fraction tilled[3]	Tilled cropland: Area	Crop sequence[4]	Nontilled adjacent cropland area
	Percent		*Tonnes/ ha*		*Tonnes/ ha per year*	*Per-cent*		*Hectares*		*Hectares*
Wasco										
Wamic l	12-20	B	11.2	34.7	0.63	15.2	0.65	2708	WF	1458
Wamic l, mdp	5-12	B	11.2	34.7	.63	7.8	.65	1177	WF	634
Wamic l, N	20-40	B	11.2	34.7	.63	28.0	.25	45	WF	136
Wapinitia si l	0-5	B	11.2	32.8	.48	2.0	.85	3079	WF	543
Wapinitia si l, dp	12-20	B	11.2	32.8	.48	15.2	.65	118	WF	63

[1]Abbreviations as defined in Soil Survey Manual (Soil Survey Staff, *1951*).
[2]Source: Soil Conservation Service. Soils Interpretations for Oregon (OR-Soils-1). Continuous reissue. Portland, Oreg.
[3]Recorded area tilled cropland divided by this number will give total area.
[4]WF = Wheat-fallow (2-yr sequence); WP = wheat-peas (2-yr sequence).

Note: Dashes indicate no land in the nontilled adjacent category.

Appendix table 3.--*Listing of soil characteristics, fixed parameters of Universal Soil Loss Equation (USLE), and crop sequence for the tilled cropland, and nontilled adjacent cropland in Major Land Resource Area B9 in 6 northeastern Oregon counties*

County and soil type[1]	Slope phase	Hydrologic group	Parameters of USLE: T^2	R_T	K	S	Fraction tilled[3]	Tilled cropland: Area	Crop sequence[4]	Nontilled adjacent cropland area
	Percent		*Tonnes/ ha*		*Tonnes/ ha per year*	*Per-cent*		*Hectares*		*Hectares*
Gilliam										
Morrow si l, mdp	2-5	C	4.5	32.1	0.48	3.2	0.85	3016	WF	532
Morrow si l, S	12-20	C	4.5	32.1	.48	15.2	.85	318	WF	56
Morrow si l, SW var	5-12	C	4.5	32.1	.48	7.8	.75	1401	WF	467
Morrow										
Morrow si l	3-7	C	4.5	32.1	.48	4.6	.85	1210	WF	214
Morrow si l	7-12	C	4.5	32.1	.48	9.0	.85	3012	WF	531
Morrow si l	20-35	C	4.5	32.1	.48	26.0	.75	6431	WF	2144
Walvan loam	20-35	C	11.2	30.9	.63	26.0	.10	749	WF	6741
Waha si l	7-12	C	4.5	38.0	.48	9.0	.40	1039	WF	1559
Waha si l	20-35	C	4.5	38.0	.48	26.0	.20	507	WF	2030
Umatilla										
Athena si l	0-3	B	11.2	39.0	.56	1.2	.95	2778	WF	259
Athena si l	3-7	B	11.2	39.0	.56	4.6	.95	2112	WF	347
Athena si l	7-12	B	11.2	39.0	.56	9.0	.95	1474	WF	121
Couse si l	3-7	C	2.2	46.8	.43	4.6	.15	224	WF	1981
McKay si l	3-7	D	6.7	32.8	.48	4.6	.97	3340	WF	161
Palouse si l	0-3	B	11.2	43.4	.29	1.2	.95	552	WF	45
Palouse si l	7-12	B	11.2	43.4	.29	9.0	.95	1934	WF	159
Palouse si l	12-20	B	11.2	43.4	.29	15.2	.95	2246	WF	185
Palouse si l	20-35	B	11.2	43.4	.29	26.0	.50	178	WF	279

Appendix table 4.--*Listing of soil characteristics and fixed parameters of the Universal Soil Loss Equation for uncultivated forest and rangeland in Major Land Resource Area B7 in 6 northeast Oregon counties*[1]

County and soil type	Slope phase	Parameters of USLE: T[3]	R_T	K	S	Hydrologic group	Area
	Percent	*Tonnes/ ha*		*Tonnes/ha per yr*	*Percent*		*Hectares*
Gilliam							
Gravden gr si l, SW	5-20	2.2	20.8	0.26	11.0	C	2241
Gravden si l, mo dp	5-20	2.2	20.8	.26	11.0	C	4108
Starbuck st si l, S	7-40	2.2	20.8	.43	20.2	D	1307
Morrow							
Ephrata sa l	0-3	2.2	17.3	.41	1.2	B	1587(.25)[4]
Ephrata sa l	3-7	2.2	17.3	.41	4.6	B	475(.10)[4]
Ephrata sa l, sh var	0-3	2.2	17.3	.41	1.2	B	3021
Koehler l sa	0-3	4.5	17.3	.26	1.2	C	8982(.10)[4]
Rockland	0-5	6.7	17.3	.38	2.5	B/D	1295
Taunton f s l	0-3	4.5	20.8	.41	1.2	C	285(.50)[4]
Taunton f s l	3-7	4.5	20.8	.41	5.0	C	3770(.50)[4]
Taunton f s l	7-12	4.5	20.8	.41	9.0	C	1942(.20)[4]
Winchester co sa	3-7	11.2	17.3	.13	4.6	A	9094
Winchester co sa	7-12	11.2	17.3	.13	9.0	A	4685
Umatilla							
Ephrata sa l	0-3	2.2	17.3	.41	1.2	B	7998(.25)[4]
Ephrata sa l	3-7	2.2	17.3	.41	4.6	B	2147(.25)[4]
Nansene si l	12-20	6.7	20.8	.56	15.2	B	154
Quincy f sa	0-3	11.2	17.0	.13	1.2	A	576(.25)[4]
Quincy f sa	3-7	11.2	17.0	.13	4.6	A	1622(.25)[4]
Quincy f sa	7-12	11.2	17.0	.13	9.0	A	2185(.25)[4]
Rockland	0-3	6.7	17.3	.38	1.2	B/D	467
Rockland	12-20	6.7	17.3	.38	15.2	B/D	792
Sand dune	0-5	11.2	17.0	.13	2.0	A	1250
Starbuck v st l	0-3	2.2	20.8	.43	1.2	D	267
Starbuck v st l	7-12	2.2	20.8	.43	9.0	D	1454
Starbuck v st l	12-20	2.2	20.8	.43	15.2	D	2141
Starbuck v st l	20-35	2.2	20.8	.43	26.0	D	559
Taunton f s l	0-3	4.5	20.8	.41	1.2	C	3296(.50)[4]
Taunton f s l	3-7	4.5	20.8	.41	4.6	C	344(.50)[4]
Taunton f s l	7-12	4.5	20.8	.41	9.0	C	998(.20)[4]
Winchester co sa	0-3	11.2	17.3	.13	1.2	A	1928
Winchester co sa	3-7	11.2	17.3	.13	4.6	A	4457
Winchester co sa	7-12	11.2	17.3	.13	9.0	A	2296

[1]Those soil types having tilled fractional area equal to zero.
[2]Abbreviations as defined in Soil Survey Manual (Soil Survey Staff, *1951*).
[3]Source: Soil Conservation Service. Soils Interpretation for Oregon (OR-Soils-1). Continuous reissue. Portland, Oreg.
[4]Number in parentheses is estimated fraction of area under intensive irrigation--hence not considered uncultivated forest and rangeland.

Appendix table 5.--*Listing of soil characteristics, fixed parameters of the Universal Soil Loss Equation for uncultivated forest and rangeland in Major Land Resource Area B8 in 6 northeast Oregon counties*

County and soil type[2]	Slope phase	Parameters of USLE: T[3]	R_T	K	S	Hydrologic group	Area
	Percent	*Tonnes/ ha*		*Tonnes/ha per yr*	*Percent*		*Hectares*
Gilliam							
Bakeoven v st l	3-12	2.2	31.1	0.13	6.6	D	971
Bakeoven-Biscuit cmplx	7-12	2.2	31.1	.13	9.0	D	1335

Appendix table 5.--*Listing of soil characteristics and fixed parameters of the Universal Soil Loss Equation for uncultivated forest and rangeland in Major Land Resource Area B8 in 6 northeast Oregon counties*[1]--Continued

County and soil type[2]	Slope phase	Parameters of USLE				Hydrologic group	Area
		T[3]	R_T	K	S		
	Percent	*Tonnes/ ha*		*Tonnes/ha per yr*	*Percent*		*Hectares*
Gilliam							
Bakeoven-Condon cmplx	3-12	2.2	31.1	0.13	6.6	D	1821
Ephrata sa l	3-7	2.2	26.0	.41	4.6	B	2064
Ephrata sa l	7-12	2.2	26.0	.41	9.0	B	324
Ephrata-Rockland cmplx	3-7	2.2	26.0	.56	6.6	B	4168
Esquatzel si l	0-3	11.2	27.2	.56	1.2	B	688
Gravden si l	0-3	2.2	27.9	.26	1.2	C	1214
Gravden si l	3-7	2.2	27.9	.26	4.6	C	9672
Gravden si l	7-12	2.2	27.9	.26	9.0	C	1538
Koehler l sa	0-3	4.5	26.0	.26	1.2	C	283
Koehler v f sa l	3-7	4.5	26.0	.26	4.6	C	1744
Koehler v f sa l	7-12	4.5	26.0	.26	9.0	C	769
Kuhl st si l	20-35	2.2	29.7	.37	26.0	D	890
Lickskillet v st l	20-35	2.2	29.7	.22	26.0	D	31878
Lickskillet v st l	35-60	2.2	29.7	.22	45.0	D	17371
Nansene rocky si l	20-35	6.7	29.7	.56	26.0	B	13675
Nansene rocky si l	35-60	6.7	29.7	.56	45.0	B	7045
Riverwash	0-3	11.2	27.2	.13	1.2	A	486
Roloff-Rockland cmplx	0-3	4.5	27.2	.56	1.2	C	1255
Roloff-Rockland cmplx	7-12	4.5	27.2	.56	9.0	C	1174
Roloff-Rockland cmplx	20-35	4.5	27.2	.56	26.0	C	9776
Roloff-Rockland cmplx	35-60	4.5	27.2	.56	45.0	C	5036
Warden si l	20-40	11.2	26.7	.37	30.0	B	2792
Starbuck st si l	7-12	2.2	28.4	.48	9.0	D	890
Starbuck st si l	20-60	2.2	28.4	.48	36.0	D	19141
Walvan l	7-12	11.2	28.4	.63	9.0	B	688
Walvan l	20-60	11.2	28.4	.63	36.0	B	10724
Yakima l	0-3	4.5	29.2	.63	1.2	B	324
Morrow							
Bakeoven v st l	2-20	2.2	31.1	.13	9.2	D	3642
Bakeoven-Morrow cmplx	2-20	2.2	31.1	.13	9.2	D	13759
Dune land	0-1	11.2	26.0	.13	.5	A	912
Lickskillet v st l	7-40	2.2	29.7	.22	20.2	D	10198
Lickskillet v st l	40-70	2.2	29.7	.22	52.0	D	20234
Nansene r si l, N	35-70	6.7	29.7	.56	49.0	B	1216
Ritzville si l	35-70	11.2	27.9	.63	49.0	B	1216
Rock outcrop-Rubble land	0-50	6.7	26.7	.38	20.0	B/D	304
Starbuck st si l	4-20	2.2	28.4	.48	12.0	D	1216
Starbuck v st si l, S	7-40	2.2	28.4	.48	20.2	D	10334
Wrentham-Rock outcrop cmplx	35-70	4.5	29.7	.48	49.0	C	13759
Sherman							
Bakeoven v st l	2-20	2.2	31.1	.13	11.0	D	2414
Condon-Bakeoven cmplx	2-20	4.5	29.7	.41	11.0	C	18447
Dune land	0-1	11.2	26.0	.13	.5	A	67
Kuhl st si l	10-35	2.2	29.7	.37	22.5	D	613
Kuhl v st v f sa l, N	7-35	2.2	29.7	.37	21.0	D	267
Lickskillet v st l, S	7-40	2.2	29.7	.22	23.5	D	4588
Lickskillet v st l, S	40-70	2.2	29.7	.22	55.0	D	14550
Lickskillet ex st l, N	40-70	2.2	29.7	.22	55.0	D	541
Nansene rk si l	35-70	6.7	29.7	.56	52.5	B	5710
Quincy l f sa	0-20	11.2	26.0	.13	10.0	A	279
Riverwash	0-1	11.2	27.2	.13	.5	A	1024
Rock outcrop-Rubble land cmplx	0-50	2.2	29.7	.13	25.0	D	10165
Roloff-Rockland cmplx	0-50	4.5	27.2	.56	25.0	C	146
Starbuck v st si l, S	7-40	2.2	28.4	.48	23.5	D	1872
Starbuck st si l	4-20	2.2	28.4	.48	12.0	D	522
Starbuck ex st si l, S	40-70	2.2	28.4	.48	55.0	D	1432

Appendix table 5.--*Listing of soil characteristics and fixed parameters of the Universal Soil Loss Equation for uncultivated forest and rangeland in Major Land Resource Area B8 in 6 northeast Oregon counties*[1]--Continued

County and soil type[2]	Slope phase	Parameters of USLE				Hydrologic group	Area
		T[3]	R_T	K	S		
	Percent	*Tonnes/ ha*		*Tonnes/ha per yr*	*Percent*		*Hectares*
Umatilla							
Bakeoven v st l	3-7	2.2	31.1	0.13	5.0	D	2976
Bakeoven v st l	7-12	2.2	31.1	.13	9.5	D	1529
Bakeoven-Biscuit cmplx	7-12	2.2	31.1	.13	9.5	D	1226
Bakeoven-Biscuit cmplx	20-35	2.2	31.1	.13	27.5	D	325
Condon-Bakeoven cmplx	3-7	4.5	29.7	.41	5.0	C	1145
Condon-Bakeoven cmplx	7-12	4.5	29.7	.41	9.5	C	2654
Condon-Bakeoven cmplx	12-20	4.5	29.7	.41	16.0	C	901
Condon-Bakeoven cmplx	20-35	4.5	29.7	.41	27.5	C	647
Lickskillet v st l	7-12	2.2	29.7	.22	9.5	D	1921
Lickskillet v st l	12-20	2.2	29.7	.22	9.5	D	2402
Lickskillet v st l	20-35	2.2	29.7	.22	9.5	D	6166
Lickskillet v st l	35-60	2.2	29.7	.22	9.5	D	11002
Minor soils	3-10	6.7	29.3	.32	6.5	C	10421
Nansene si l	20-35	6.7	29.7	.56	27.5	B	850
Roloff-Rockland cmplx	20-35	6.7	27.2	.56	27.5	B/D	3738
Starbuck v st si l	7-12	2.2	28.4	.43	9.5	D	2070
Starbuck v st si l	12-20	2.2	28.4	.43	16.0	D	2034
Starbuck v st si l	20-35	2.2	28.4	.43	27.5	D	1367
Starbuck v st si l	35-60	2.2	28.4	.43	47.5	D	1686
Wasco							
Bakeoven v st l	2-20	2.2	31.1	.13	11.0	D	4330
Condon-Bakeoven cmplx	0-12	4.5	29.7	.41	11.0	C	41480
Lickskillet ex st l	40-70	2.2	29.7	.22	55.0	D	31565
Lickskillet v st l	7-40	2.2	29.7	.22	23.5	D	15783
Maupin-Stony land cmplx	0-12	4.5	28.4	.48	6.0	C	4654
Nansene rk si l	35-70	6.7	29.7	.56	52.5	B	2355
Riverwash	0-1	11.2	27.2	.13	.5	A	2355
Roloff-Rockland cmplx	0-50	4.5	27.2	.56	25.0	C	1449
Rock outcrop-Rubble land cmplx	0-50	2.2	29.9	.13	25.0	D	1268
Sherar v cobbly l	5-45	4.5	27.9	.31	25.0	C	5253
Skyline-Hesslan cmplx	40-65	2.2	34.7	.22	52.5	D	4166
Wamic-Skyline-Rocky cmplx	2-20	11.2	34.7	.41	11.0	B	1630
Wapinitia-Bakeoven cmplx	5-12	11.2	32.8	.48	8.5	B	4528
Wrentham rk si l	35-70	4.5	29.7	.48	52.5	C	3804
Wrentham rk si l, N	35-70	4.5	29.7	.48	52.5	C	4528

[1]Those soils types having tilled fractional area equal to zero.

[2]Abbreviations as defined in Soil Survey Manual (Soil Survey Staff, *1951*).

[3]Source: Soil Conservation Service. Soils Interpretations for Oregon (OR-Soils-1). Continuous reissue. Portland, Oreg.

Appendix table 6.--*Listing of soil characteristics and fixed parameters of the Universal Soil Loss Equation for uncultivated forest and rangeland in Major Land Resource Area B9 in 6 northeast Oregon counties*[1]

County and soil type[2]	Slope phase	Parameters of USLE: *T*[3]	R_T	*K*	*S*	Hydrologic group	Area
	Percent	*Tonnes/ha*		*Tonnes/ha per yr*	*Percent*		*Hectares*
Gilliam							
Lickskillet v st l, S	7-40	2.2	29.7	0.22	20.2	D	560
Morrow							
Lickskillet v st l	7-12	2.2	29.7	.22	9.0	D	1805
Lickskillet v st l	20-35	2.2	29.7	.22	26.0	D	8708
Lickskillet v st l	35-60	2.2	29.7	.22	45.0	D	4240
Morrow si l	35-60	4.5	32.1	.48	45.0	C	1664
Rockly ex st l	3-12	2.2	43.4	.37	7.0	D	997
Rockly ex st l	20-35	2.2	43.4	.37	26.0	D	1233
Rockly ex st l	35-60	2.2	43.4	.37	45.0	D	575
Snell v st si l	20-35	2.2	43.4	.13	26.0	C	2791
Snell v st si l	35-60	2.2	43.4	.13	45.0	C	1438
Umatilla							
Hurwal si l	20-35	11.2	35.7	.31	26.0	B	1482
Hurwal si l	35-60	11.2	35.7	.31	45.0	B	11247
Rockly ex st l	20-35	2.2	43.4	.13	26.0	D	1421
Rockly ex st l	35-60	2.2	43.4	.13	45.0	D	977
Rockly-Waha cmplx	3-7	4.5	43.4	.41	4.6	C	179
Rockly-Waha cmplx	7-12	4.5	43.4	.41	9.0	C	1408
Rockly-Waha cmplx	12-20	4.5	43.4	.41	15.2	C	547
Snell v st si l	20-35	2.2	43.4	.13	26.0	C	6755
Snell v st si l	35-60	2.2	43.4	.13	45.0	C	39598
Wallowa							
Albee-Anatone cmplx	0-12	4.5	34.7	.41	4.8	B/D	1091
Hurwal st si l	30-50	11.2	34.7	.31	38.0	B	1310
Hurwal-Rock outcrop cmplx	50-75	11.2	34.7	.31	60.0	B	10043
Illahee si l	1-3	4.5	34.7	.32	1.8	C	3930
Imnaha v st l	50-75	4.5	34.7	.13	60.0	B/D	218
Imnaha-Rock outcrop cmplx	50-75	4.5	34.7	.13	60.0	B/D	3711
Klicker v st si l	15-45	2.2	34.7	.40	27.0	C	1528
Klicker-Snipe cmplx	15-45	2.2	34.7	.40	27.0	C	218
Nebo gr l	0-2	6.7	34.7	.26	.8	A	218
Snell st si l	1-15	2.2	34.7	.13	6.6	C	26854
Snell st si l	45-75	2.2	34.7	.13	57.0	C	4148
Snell v st si l	1-15	2.2	34.7	.13	6.6	C	6331
Snell v st si l	15-45	2.2	34.7	.13	27.0	C	19430
Snell v st si l	45-75	2.2	34.7	.13	57.0	C	27071
Snell-Rock outcrop cmplx	45-75	2.2	34.7	.13	57.0	C	16592
Tolo si l	12-20	11.2	34.7	.71	15.2	B	5676
Tolo si l	20-45	11.2	34.7	.71	30.0	B	1747
Tolo si l	45-75	11.2	34.7	.71	57.0	B	873
Tolo-Rock outcrop cmplx	45-75	11.2	34.7	.71	57.0	B	3711
Topper si l	1-15	11.2	34.7	.41	6.6	C	1091
Wrentham-Rock outcrop cmplx	45-75	4.5	34.7	.48	57.0	C	9824

[1] Those soil types having tilled fractional area equal to zero.

[2] Abbreviations as defined in Soil Survey Manual (Soil Survey Staff, *1951*).

[3] Source: Soil Conservation Service. Soils Interpretations for Oregon (OR-Soils-1). Continuous reissue. Portland, Oreg.

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